SEPTEMBER 1974

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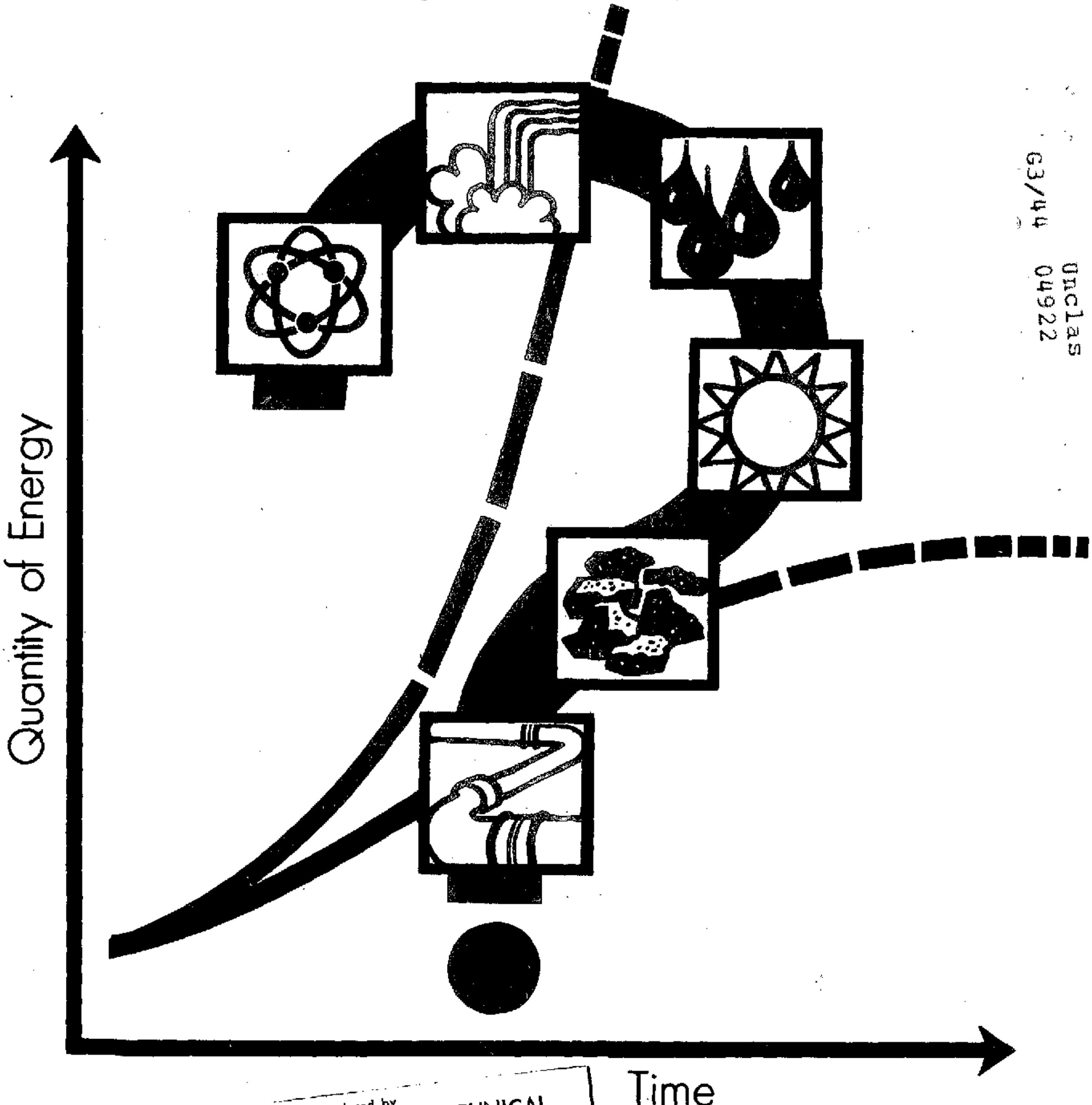
MEGASTAR

The Meaning of Energy Growth: an Assessment of Systems, Technologies, And Requirements



SCHOOL OF ENGINEERING
AUBURN UNIVERSITY
AUBURN, ALABAMA

FINAL REPORT

NASA GRANT NGT 01-003-044

NASA/ASEE SYSTEMS DESIGN SUMMER FACULTY PROGRAM

We make a product which must be available when called for by the customer ... We can't refuse to accept an order ...

Joseph M. Farley, President
Alabama Power Company

The shrewd guess, the fertile hypothesis, the courageous leap to a tentative conclusion - these are the most valuable coins of the thinker at work.

Jerome S. Bruner

The younger generation will be facing the future with honesty only when it brings itself to face the strain of thinking through the consequences, tangible and intangible, certain and speculative, of the current drift into the future, and in doing so, recognizes that ... on many issues painful choices have to be made ...

Ezra Mishan, The Costs of Economic Growth

Look afar and see the end from the beginning.

Fortune Cookie

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M E G A S T A R

The Meaning of Energy Growth: An Assessment of Systems, Technologies And Requirements

by

AUBURN UNIVERSITY ENGINEERING SYSTEMS DESIGN

SUMMER FACULTY FELLOWS

FINAL REPORT

CR-120338

Prepared Under

CONTRACT NGT 01-003-044

UNIVERSITY AFFAIRS OFFICE HEADQUARTERS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

with the cooperation of

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

and

SCIENCE AND ENGINEERING
GEORGE C. MARSHALL SPACE FLIGHT CENTER
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ABSTRACT

MEGASTAR presents a methodology for the display and analysis of postulated energy futures for the United States. A systems approach methodology including the methodology of technology assessment is used to examine three energy scenarios--the Westinghouse Nuclear Electric Economy, the Ford Technical Fix Base Case and a MEGASTAR generated Alternate to the Ford Technical Fix Base Case. The three scenarios represent different paths of energy consumption from the present to the year 2000. Associated with these paths are various mixes of fuels, conversion, distribution, conservation and end-use technologies. MEGASTAR presents the estimated times and unit requirements to supply the fuels, conversion and distribution systems for the postulated end uses for the three scenarios and then estimates the aggregate manpower, materials, and capital requirements needed to develop the energy system described by the particular scenario. The total requirements and the energy subsystems for each scenario are assessed for their primary impacts in the areas of society, the environment, technology and the economy. MEGASTAR suggests areas for detailed study and raises issues for discussion.

MEGASTAR represents the result of an educational effort in systems approach methodology. Thus MEGASTAR presents a display of the energy dilemma as seen by the study participants who initially lacked detailed background in the energy area.

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We wish to express our thanks to Dr. W. R. Lucas, Director of MSFC; Mr. J. S. Potate, Associate Director; Colonel E. O. Mohlere, Assistant to the Director; Dr. R. G. Smith, Director of Science and Engineering; Dr. F. B. Moore, Director, Electronics and Controls Laboratory; Dr. Ernst Stuhlinger, Associate Director for Science; and especially to Dr. George Bucher, Deputy Associate Director for Science, who gave us advice and support throughout the program. Mr. Jim Miller and our NASA Co-Directors, Mr. Lelous Wood and Mr. Carl Nagle also deserve our particular appreciation. Our thanks also go to Mr. Don Merrifield and Mr. Walter Kirsch of Sperry Rand, who attended many of our sessions and contributed many helpful suggestions.

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The success of any program depends on the resource material that is made available to the participants. The NASA Regional Information Center and the Redstone Scientific Information Centers are run by dedicated, capable and helpful librarians. These two centers have, over the years, provided excellent support to the NASA/ASEE programs and we sincerely appreciate the efforts of all of the professionals who assisted us, especially Ms. Charlotte Dabbs of NASA and Mr. Jim Clark of RSIC.

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The continued support and funding of these summer programs are due to Mr. Frank Hansing and Mr. Charles Carter of the Office of University Affairs at NASA Headquarters. Mr. Hansing and Mr. Carter, along with Mr. Francis X. Bradley of ASEE Headquarters, and their many associates, certainly deserve recognition by the education community for their sustained efforts in providing programs that are of great benefit to educators, NASA, and society in general.

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INTRODUCTION

It is clear that the United States has had an energy problem during the last year due to the imbalance between shortages in supply and increasing demand. The history and projection of energy growth on the basis of historical patterns as shown in Figures 1 and 2 suggest what U.S. energy consumption may be in the future and also suggests that shortages may become prevalent without a new energy policy.

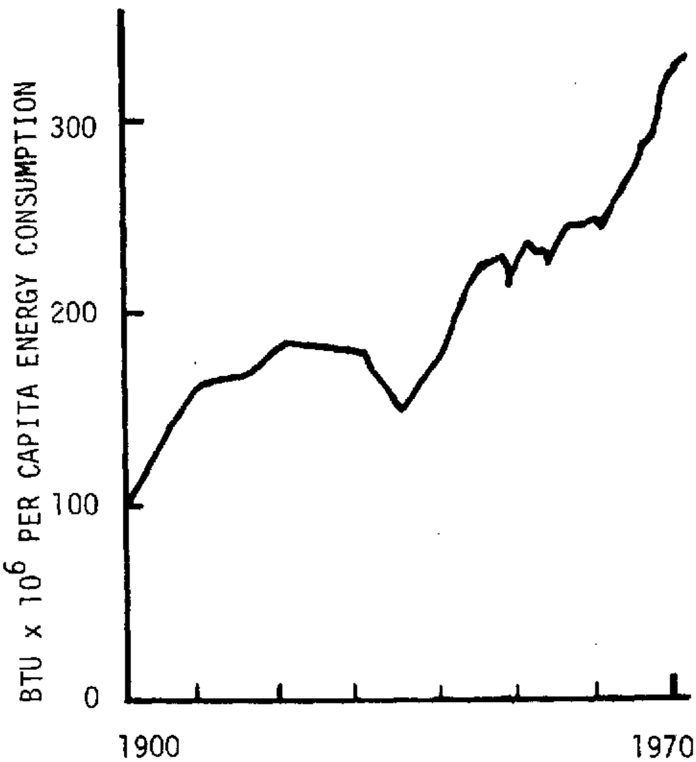


FIGURE 1. Total Per Capita U.S. Energy Consumption

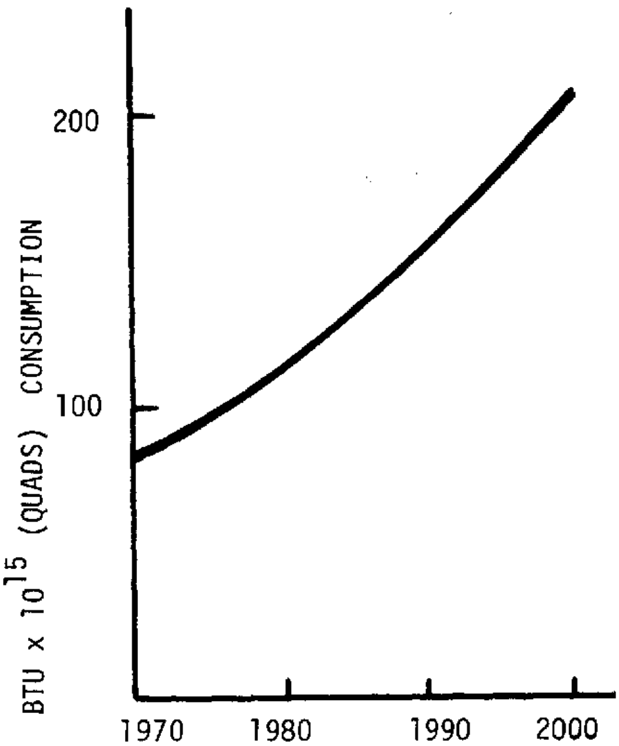


FIGURE 2. Projected U.S. Energy Consumption on Basis of Historical Growth

It is not clear what future United States energy policy should be. One of the prerequisites of any policy development is the availability of reliable information. There have been a number of studies of the U.S. energy problem within the last two years and, although it is occasionally difficult

to sift the wheat from the chaff, a fairly consistent picture is emerging in terms of present energy resources, conversion, distribution, end use, and present lack of a consistent energy policy. The other side of the energy policy question, namely, what should be the future U.S. energy policy is still undergoing vigorous debate and the only apparent agreement is that such a policy is urgently needed. There have also been several recent proposals or scenarios concerning future energy policy. It is important that these proposals and other alternatives be carefully analyzed and given the widest possible dissemination and debate in order to produce the best policy for the future development and use of energy.

The purpose of this study is to provide a methodology for assessing alternate energy futures and to apply that methodology to the critical evaluation of two recently proposed energy scenarios. These are the Nuclear Electric Economy proposed by Westinghouse and others [Creagan-74] [Ross-73] and the Ford Foundation Energy Policy Report's technical fix scenario, base case [Ford-74]. Although both of these scenarios represent considerable effort on the part of both groups, they are still broad brush in their descriptions. It is the objective of this study to analyze in more detail the requirements necessary to realize each of these scenarios and the impacts of those requirements on our society. It is felt that this type of examination of the consequences of various energy futures is a prerequisite to the development of a satisfactory energy policy. Decision-makers and society at large should have the greatest possible awareness of the implications of alternate policies before decisions are made, not after. Since many of the decisions concerning energy that will be made in the next few years will set the course of our society until the end of the century, it is imperative that these decisions be made with the best possible information. It is hoped that this report will supply some of the information necessary for the effective functioning of the decision-making process.

The reader of MEGASTAR is faced with the dilemma of what section of MEGASTAR is important to him. The writers in preparing the report faced the dilemma of reporting what had been learned and done in 11 weeks. The reporting dilemma was compounded by the fact that the contributors were undergoing a continual metamorphasis during the 11 weeks from eighteen individuals relatively unversed in the energy problem to the MEGASTAR group that gained the status of a cohesive and knowledgeable systems approach task force as time ran out. This is reflected in the report. The appendices contain detailed information on the basic elements of our national energy system. The numbers in the appendices are continually subject to refinement. The body of the report attempts to carry the reader through a demonstration of a systems approach methodology including technology assessment. This methodology was applied to an examination of two proposed energy scenarios [Ross-73] and [Ford-74] and an alternate scenario proposed by MEGASTAR for purposes of discussion.

This demonstration is preceded by a statement of the energy dilemma as seen by the MEGASTAR group. The methodology is then explained in Chapters 2

through 4. Various scenarios and energy futures are discussed in Chapters 5 through 7. Chapters 8, 9, and 10 are the results of three separate applications of the methodology which was being developed to the three scenarios chosen for analysis. It is interesting to note that three separate task teams examined the three scenarios. Thus, there exist differences in presentation and emphasis in Chapters 8, 9, and 10 although coordination of effort existed between the three MEGASTAR task teams. Chapter 11 represents an effort by the entire MEGASTAR group to present statements agreed to by all. Unity of action was the theme of the MEGASTAR group but independence of thought was the essence of the effort to insure intellectual honesty in results on the basis of the information obtained. Armed with these remarks, the reader is guided with the Table of Contents to the chapter or chapters of his choice.

This study was produced by the NASA-ASEE sponsored Auburn University Summer Faculty Systems Engineering Design Program at the Marshall Space Flight Center. The study group consisted of eighteen faculty members from colleges and universities all over the nation. The majority of the group were engineers, physicists, and chemists, but there were also members with backgrounds in economics, environmental science and political science. The study was performed during the summer of 1974. A complete description of the study group and the study organization is given in Appendix H.

This study was intended primarily as an aid for decision-makers at all levels of government and industry. It is also hoped that citizens will make use of the information in this and other reports to inform themselves of the feasible energy policy alternatives which are open to our society. The question of energy is one of the major problems facing this nation and the ultimate policy decision should be based upon the widest possible debate and the most careful scrutiny of all feasible alternatives.

CHAPTER 1. THE PRESENT PROBLEM

The present energy problem in the U.S. is multifaceted and cannot be stated in a concise form that would represent every viewpoint. For example

> To the business owner it may be rising prices for the fuel and electricity he uses.
>
> To the motorist it may be uncertainty regarding gasoline availability on a Sunday during his vacation in another state.
>
> To the economist it may be concern about international prices and markets and multinational corporate, monopoly or cartel control of the market.
>
> To the politician it may be an uncomfortable alliance brought about by dependence on the resources of another country.
>
> To the scientist or engineer it may be an opportunity to develop new technology for providing energy systems and end use devices.
>
> To the utility industry it is new problems in finding capital, power plant sites, generating equipment, transmission right-of-way and equipment, and manpower to meet the historically projected demand of a growing nation with a tight money supply.
>
> To the energy industry it is a challenge to meet present demand and to prepare to meet future fuel demands that are uncertain as to form as well as quantity.
>
> To everyone it is increasing prices and fear about the availability of electric power, heating fuel, transportation fuel and ultimately his life style.

In short it is a dilemma to the individual and to the nation, it is a dilemma that must be resolved. Furthermore, the dilemma embodies energy resources, energy generation and conversion systems, distribution of energy, conservation of energy and the many end uses of energy. The dilemma is interrelated to other aspects of society and hence has political, social, economical, environmental and cultural dimensions.

The first step to resolving the dilemma must be a definition of the dilemma in terms common to each sector of society. Then the citizens of the U.S. can participate in the orderly process of government to resolve this dilemma. This chapter presents the beginnings of a definition of the dilemma as the MEGASTAR group viewed the problem subsequent to an information analysis process.

1-1 THE U.S. ENERGY DILEMMA

1-1-1 CONCERNS ABOUT OIL AND GAS

The United States has a long history of predictions that the nation would face shortages of oil and consequent energy crises. The oil industry historically has made very conservative estimates of the oil resources in the U.S. There has been a feeling in the industry that it would have to produce whatever oil (or gas) that it predicted could be found. Predictions have been made on the basis of exploration experience, and the oil and gas predicted to be discoverable has always been based on a high degree of confidence in new discoveries. Those not familiar with the circumstances of these forecasts have, from time to time, made alarming forecasts regarding impending shortages. Even the Department of the Interior during the 1920s and 1930s fell into this pattern. However, since then, the Department of the Interior has been making independent forecasts and has had more confidence in the future. Throughout the period of shortage forecasts, the oil industry has remained unconcerned. In spite of historical conservatism in official forecasts, people in the field know that more oil than predicted has always been found, and have always been optimistic that they could continue to find more.

What, then, is different about the current energy "crisis"? In the last twenty years the two groups that forecast oil and gas resources, the oil industry and the Department of the Interior, have shown no concern that there may be shortages. Figure 1-1 illustrates the historical rise in oil and gas production and approximately steady coal production. Imports of oil and, after 1955, gas were increasing gradually. Gradual declines in additions to proved reserves since about 1955 with the consequent gradual decline in the ratio of reserves to production for both oil and gas prompted growing prediction of shortages to arise again about 1970. The National Petroleum Council organized a Committee on the U.S. Energy Outlook to conduct a study of the prospects for the future. The participants included representatives from the oil, gas, and coal industries, the Atomic Energy Commission, and Department of the Interior. The Committee predicted consumption (primarily by extrapolation) and available energy resource production to 1985. The shortfall of production below consumption was allocated to imports of gas and oil. Figure 1-2 shows the results of considerable sub-committee work resulting in the initial forecast [NPC-71]. The small amount of energy from geothermal sources does not show up in the figure. The preliminary results of the NPC study and an assessment of what would be required to meet the projections were presented with little apparent concern regarding the feasibility of the projection.

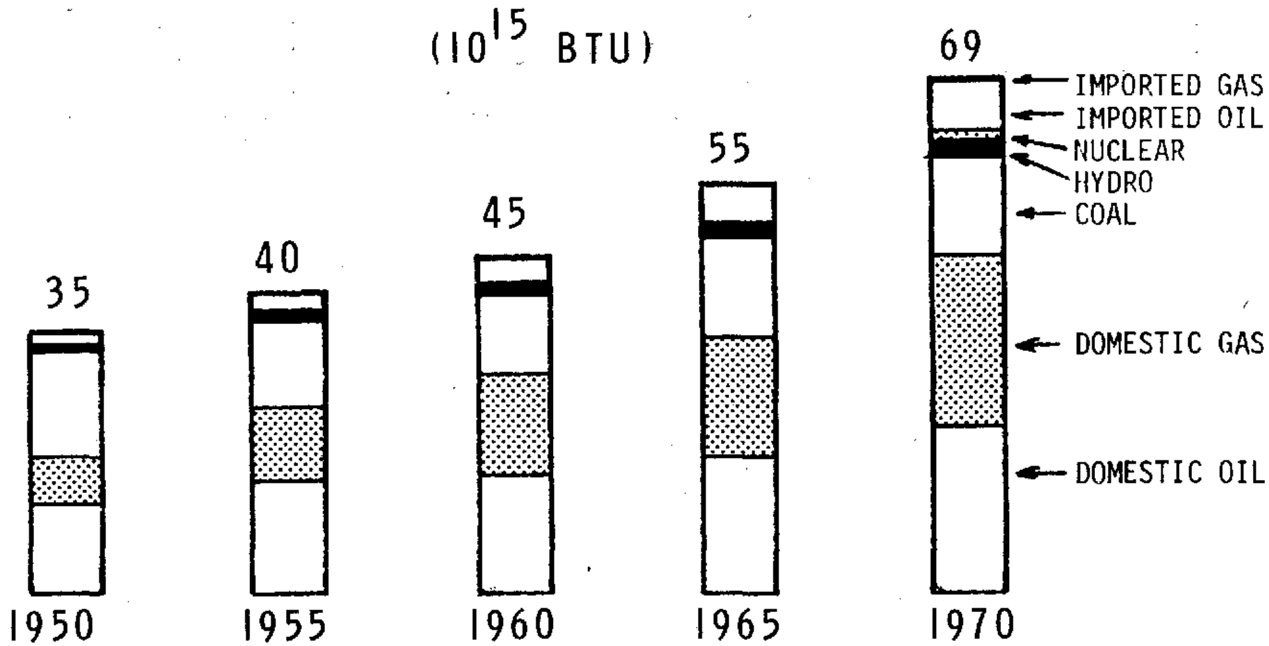


FIGURE 1-1 U.S. ENERGY CONSUMPTION

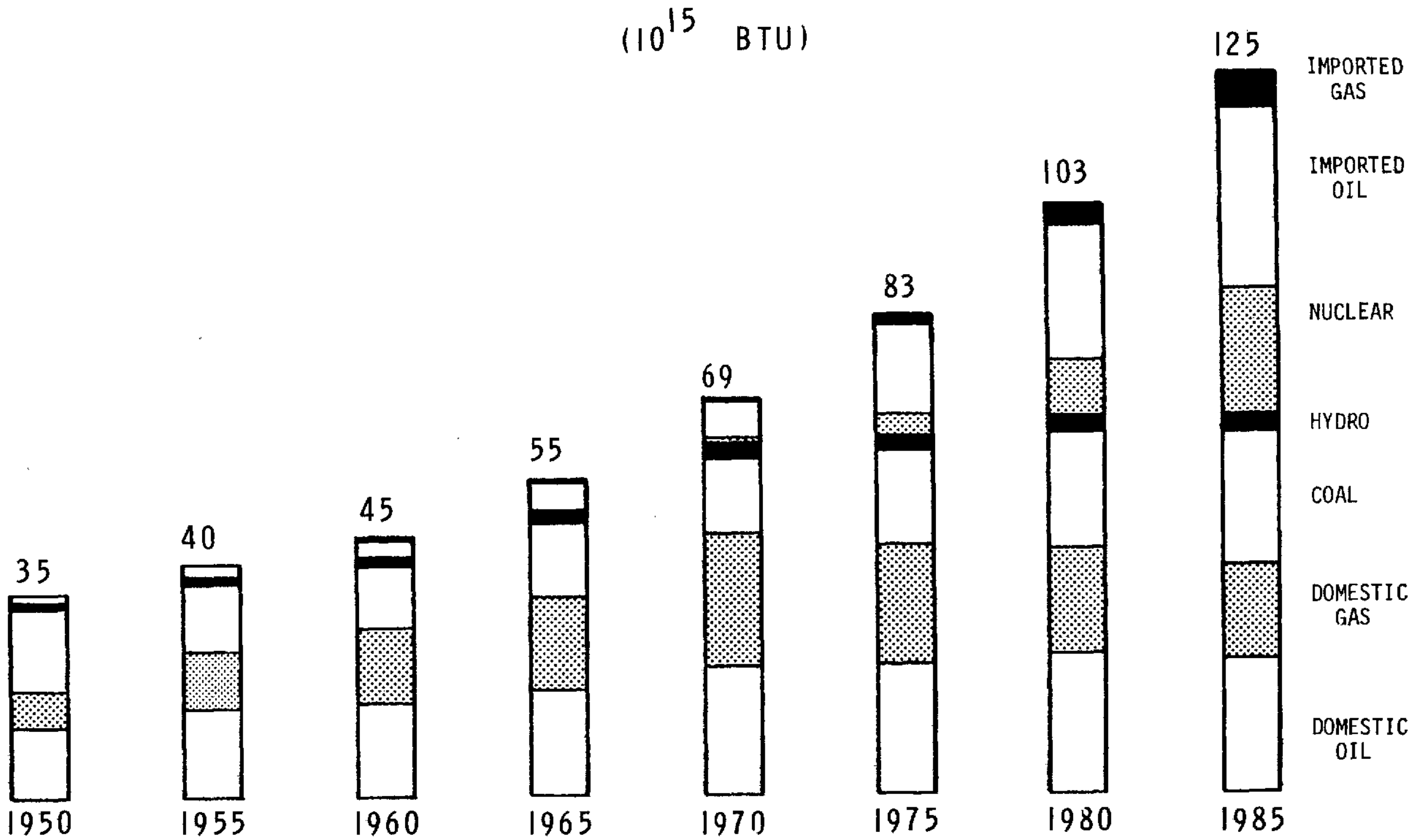


FIGURE 1-2 U. S. ENERGY CONSUMPTION AND THE NATIONAL PETROLEUM COUNCIL PROJECTION. [NPC-71]

Subsequent analysis of the study resulted in statements of two general concerns. The first concern was that the oil and gas industry itself expected oil production to level off and gas production to decline. The second concern was with the rapid growth of imports that was predicted (imports were predicted to grow from 12% of all energy in 1970 to 30% of a much larger total in 1985). Problems with balance of payments in foreign trade, pollution from oil spills, and relations with foreign sources of oil were anticipated. The oil industry itself had predicted possible energy problems and apparently believed the prediction. This, in addition to the emergence of problems with rapid import growth, differentiates the current problem from past shortage predictions.

The nation has just passed through a period of oil and oil product shortages caused primarily by the trade embargo by the Arab countries along with some localized distribution problems. This situation was labeled the "energy crisis". Because the U.S. was able to reduce consumption considerably and because domestic production and imports are now up to pre-embargo levels there is now a feeling that the "crisis" is over and oil will be abundant. However, the concerns outlined in the previous paragraph have not disappeared. The expectation remains that oil and gas discovery will decline and a high level of imports will be required. Imports may be reduced now because of some reduction in consumption. However, this reduction is apparently not very large and it may prove to be temporary. In fact, the concerns about balance of trade are now considerably compounded. A few years ago foreign oil was less than $3 per barrel whereas the current price ranges from $12 to $15. The effect of oil imports on balance of trade has significantly increased. The dilemma of increased imports has not disappeared.

1-1-2 UNCERTAINTY REGARDING OIL & GAS RESOURCES

Since the Department of the Interior had been misled in the past by conservative oil industry forecasts, the DOI forecasts of oil and gas resources have since been more optimistic than those of the industry. This remains true today and a debate has developed recently between the DOI and Mobil Oil, speaking for some of the oil industry. Figure 1-3 shows the contrast between Mobil's expectation and the DOI (U.S. Geological Survey) expectation regarding the recoverable oil and gas which remains undiscovered in the U.S. Mobil expects far less oil and gas to be discovered than does DOI, and, in addition, it appears that Mobil is adamantly supporting its figures. The Mobil predictions represent about 20 times current annual production, whereas the U.S.G.S. estimates range from 45 to 90 times current production. The considerable uncertainty created by this conflict of estimates adds to the energy dilemma, and makes formulation of rational energy policy more difficult.

1-1-3 A CONFUSING MULTITUDE OF OPTIONS

There is a very large array of possible options to provide secure

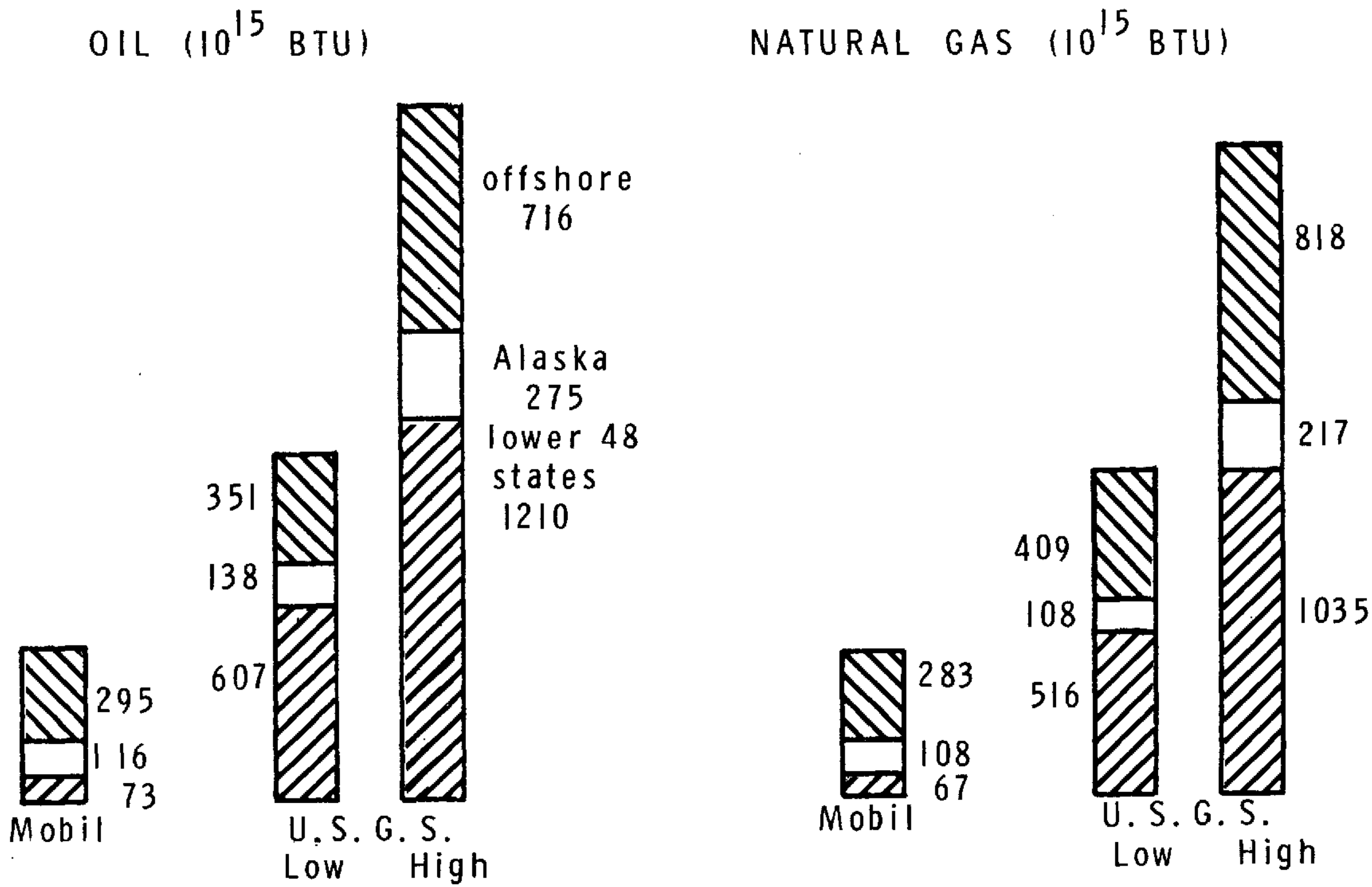


FIGURE 1-3 THE DEBATE OVER HOW MUCH RECOVERABLE OIL AND GAS IS STILL UNDISCOVERED IN THE U. S. [Gillette-74]

long term energy supplies. There is a long list of possible and hopefully possible sources to replace oil and gas including nuclear fission energy (burner and breeder power plants), coal (and synthetic oil and gas made from coal), oil from shale, geothermal energy, wind power, trash (as a direct fuel and as a source for synthetic fuel), tidal energy, ocean thermal gradients, solar energy (for heating and cooling, generation of electricity, or photosynthetic conversion to fuel), and nuclear fusion energy. However, it is not clear which of these should be developed because the costs and consequences are unclear. There is a similar long list of options for converting fuel to electricity including magnetohydrodynamic (MHD) conversion, combined cycles, binary cycles, steam plants, gas turbine plants, fuel cells, and, for solar energy, photoelectric and thermal conversion. Again the costs and consequences are unclear.

There are even some possible options for how energy is used. Presently about 20 per cent of the energy consumed in the U.S. is converted to electricity before use. Solar energy and fusion energy are expected to be the primary sources for the 21st century, and these are most conveniently used to generate electricity since they are not portable or directly distributable. Therefore, there is some basis for arguing that energy usage should gradually transform predominately to electrical. On the other hand conversion of fuels to electricity currently is accomplished with 30 to 40 percent efficiency and the remaining energy usually is lost as heat. It is not clear whether it will be better for heating purposes to use electricity or burn the fuel as the heat source. Similarly there is a choice between continuing to develop fuel burning vehicles or converting to electric powered vehicles. Also it is currently being argued that current use of energy could be reduced substantially without sacrificing style and standard of living by eliminating unnecessary use and using more efficiently that which is necessary. Again the costs and consequences of this are not clear.

In recent years several organizations have made proposals combining the options into balanced and fairly comprehensive energy scenarios. Several of these are summarized and compared in Chapter 5. Scenarios are very useful in proposing a context for each of the individual options, thereby clarifying the role of each component. However, the proposed scenarios add to the dilemma because they differ substantially and at the same time purport to be "best" ways of meeting one objective or another. There is even a multitude of proposals for the "best" way to achieve national energy independence, which is a simple objective compared to others that have been formulated. There is clearly a multitude of options and, worst of all, there is no clear consensus as to guidelines or criteria for choosing among the options.

1-1-4 UNCERTAINTY AS TO HOW TO IMPLEMENT THE CHOSEN OPTIONS

Most of the organizations that propose courses of action for the future (scenarios) do not discuss how the plan could be implemented. Some of the scenarios require substantial change in certain components of energy production or consumption. Virtually all the scenarios would require some degree of planning in the energy sector of what is essentially

an unplanned economy in the U.S. Especially on the consumption side, a great deal of value is placed on freedom of choice in the U.S., and imposing choice by legislation would not be easily accomplished nor should it be lightly undertaken.

Some economists have unbounded faith in prices and the market mechanism to solve the problem of allocation and rationing of energy resources. They argue that removing all statutory restraints that affect prices would result in natural movement in prices. Price rises would stimulate production and discourage consumption to bring them into balance. This approach would permit maximum freedom of choice for both producers and consumers. Rising prices would also naturally stimulate the development of new energy technology to replace the old sources as they become too costly. There is a good basis for the argument since many of the decisions of producers and consumers are strongly influenced by price. The asserted effects do exist and trends are identifiable [Houthakker-74]. However there is still some disagreement as to quantitative relationships between price and supply (supply elasticity) and between price and demand (demand elasticity) [MIT-74]. It is also not clear that the market mechanism rations a resource as it approaches exhaustion. Competitive pressures tend to depress prices somewhat, especially for resources that are quite inexpensive to produce relative to their value. U.S. companies that produce oil and gas have the freedom to buy coal and uranium resources so they need not fear going out of business when oil and gas resources are depleted. The only means the market mechanism includes for anticipating and compensating for resource depletion with rising prices is the futures market, and none exists for oil or gas. A proposal is just now being made for a futures market in oil [BUS. WK.-74-3] but the proposed market would handle only imported oil (which is likely to outlast domestic oil). Even the futures market does not look much beyond a year into the future.

There is some validity in the argument for letting prices allocate energy resources because the market mechanism <u>does</u> operate in the U.S. even though hampered by legislative controls, lack of completely free competition, and prices that do not always reflect full costs because of tax breaks and unaccounted externalities. However, using the market with no other controls seems quite haphazard and untrustworthy in the face of feared future problems. The feeling arises in times of difficulty that a course should be followed which minimizes uncertainty and the likelihood of disruptions. This would involve controlling or interfering with the usual operations of free markets. The history of such control or interference with market mechanisms is one of mixed success. Many such attempts have been successful (such as the stimulation of wildcat oil exploration activity by the oil depletion allowance) and many have had unforeseen bad effects (such as control of the well-head price of natural gas). The desire in developing energy scenarios, in many cases, is to plan the production and consumption of energy to meet some particular set of objectives and it is not always clear that the necessary intervention will have the desired results and only those results.

It is important to note that, even though there are many options open

to the Government to implement a chosen policy, there are also many possible options not open in the U.S. for political reasons. The Environmental Protection Agency has been discovering this in recent years. The important point at this stage of the discussion is that there is a need for a clear picture of the viable options for implementing energy policy and the consequences. The absence of this clear perspective is part of the dilemma.

1-1-5 SUMMARY OF THE DILEMMA

Several aspects of the energy dilemma have been identified:

There is rapid growth in consumption and declining production of oil and gas resulting in rapid growth in dependence on costly and unreliable foreign sources.

There is considerable uncertainty regarding domestic oil and gas resources.

There is a large array of possible options and few clear guidelines for choosing among them.

It is not clear how to implement the chosen options, i.e. how to plan one sector of an unplanned economy.

The most important thing to emphasize is that none of the elements of the energy dilemma have disappeared. The "energy crisis" may be over, but the dilemma remains.

1-2 THE CURRENT U.S. SITUATION

1-2-1 FUEL USAGE OUT OF PROPORTION WITH AVAILABILITY

There are a number of characteristics of the current energy situation in the U.S. which complicate the expected problems and limit choices for the future. One of these is the disparity between the fuels used and their abundance. Portability and ease of transport (relative to energy content) are important in determining which fuels are used most. Form and composition of the products of combustion have recently become important characteristics because of air pollution standards. As a result of these considerations, oil and gas have risen in importance as fuels while coal, in terms of relative use, has declined. As a result of air pollution standards an even higher value has been placed on natural gas and low-sulfur oil. At the same time natural gas and oil seem to be the resources expected to decline in availability. Coal is abundant in the U.S. but is not used in proportion to its abundance. Switching to more dependence on coal will not be easily accomplished.

1-2-2 AVAILABLE IMPORTS COULD UNDERCUT COAL AND SHALE OIL DEVELOPMENT

Coal is abundant in the U.S. but has undesirable characteristics as a

fuel. It is less portable than oil or gas; it is not suitable for use in engines used for transportation; and it has undesirable combustion products such as particulates and sulfur dioxide. However, coal can be converted to gaseous or liquid hydrocarbon fuels with all the desirable properties of these forms. Shale containing oil is also abundant and available near the surface in the western U.S. Gasification or liquefaction of coal and extraction of liquid petroleum from shale are feasible means of providing fairly large quantities of liquid and gaseous fuels. The cost of the resulting fuels would be higher than the cost of current domestic oil and gas resources and would certainly be higher than the cost of producing oil and gas by the Organization of Petroleum Exporting Countries (OPEC) members. Although OPEC prices are currently high (much higher than actual production costs) there is no guarantee they will remain high. Development efforts in shale oil and coal conversion could be undercut in the future by the availability of low price, imported oil and gas. Under these circumstances development of oil shale and coal for conversion to liquid or gas is likely to remain on a very small scale.

1-2-3 UNEVEN GOVERNMENT SUPPORT OF ENERGY SOURCES

As nuclear fission energy has become more prominent as a source for conversion to electricity, there have been complaints that nuclear energy is competitive only because of Government support. Nuclear energy development, fuel processing, and waste disposal have been largely supported by Government funding. There is a current commitment to movement toward a self-sustaining nuclear industry with its own fuel processing capability and corresponding fuel prices reflecting full cost. However, the Federal Government is still a strong partner in the development of future nuclear technology such as the breeder reactor program, and, because of the need for regulation and control, the Federal Government plans to continue to be the agency disposing of nuclear wastes. Even if the Government chooses to charge users of nuclear energy for the waste disposal service, there is considerable flexibility in the charges for land rent, administrative costs, and other overhead. It is not argued that the Federal Government should not be participating in nuclear development. However, this participation does obscure the true costs and value of nuclear energy relative to other energy options.

The oil and gas industries are also supported and encouraged by the Government, but to a lesser extent. The oil depletion allowance and other tax breaks are designed to help the industry generate the capital needed for exploration for new resources. Import controls have been used in the past to guarantee a market for domestic production. The coal industry to a still lesser degree is supported by a depletion allowance. Government support of energy has been generous in the past to help provide abundant, cheap energy for economic development. This could be considered to be part of the cause for present problems and certainly obscures the true role, cost, and value of various energy resources.

1-2-4 HORIZONTAL INTEGRATION OF ENERGY INDUSTRY

Oil is clearly a non-renewable resource, at least in the time frame

of human history. From the point of view of oil producers, it makes sense to invest in the energy resources that might be expected to replace oil as it is depleted. Since the oil industry represents an important segment of the U.S. economy it could further be argued that ownership of other fuels by the oil industry could contribute to minimum disruption of the economy (such as direct and indirect employment and the stock market) as the transition to other fuels takes place. Approximately 72 percent of natural gas, 30 percent of coal resources, and 50 percent of uranium resources in the U.S. are owned by companies which can be identified as primarily oil producers [Ruttenberg-73]. Oil companies are strong participants in the nuclear industry through fuel processing and even through production of nuclear reactors. Oil companies are also purchasing geothermal resource rights and are expanding in this area. All of this is sensible activity for oil company investment, but it does create a problem. As discussed earlier it might be considered desirable to let an unbiased and unobstructed fuels market allocate and ration fuels. However, the fuels market can regulate prices, supply, and demand only if a competing fuel can take some of the market away from a fuel that is overpriced and thus drive its price back down. This prevents a supplier from charging more than the production cost and relative abundance of his product would allow. In a recent econometric study, Nordhaus [Nordhaus-73] concluded that oil prices (domestic and foreign) are higher than justified by production cost and abundance of oil relative to competing fuels. If this is true, economic theory would predict that enough energy consumers would shift to competing fuel, probably coal or nuclear power, to force oil prices back down. Under present circumstances oil companies could influence coal prices or uranium prices so that the shift does not occur and the desired natural control on prices is not achieved. It is not intended to assert that oil companies do or would influence prices of competing fuels to serve their own interests. However, the possibility of this occurring necessarily limits and influences energy policy choices that can be made.

1-2-5 THE ENERGY COST OF ENVIRONMENTAL PROTECTION

During recent years there has been a growing awareness in the U.S. that some of the by-products and side effects of modern industrial society degrade the environment to the point of unpleasantness or even damage to human health. This fairly recent awareness resulted in considerable debate and the conclusion that air, land, and water could and should be cleansed of industrial and municipal wastes and kept clean. The Environmental Protection Agency, which was formed to accomplish the clean-up task, has moved rapidly and, through exercise of its rather broad powers, urged deadlines for change that reflect a sense of great urgency. EPA standards currently or soon to be enforced have considerable direct impact on fuel consumption. Pollution standards on automobiles have caused a steady, discernible increase in gasoline consumption. Sulfur dioxide limits on emissions from fuel burning plants will, at least initially, force use of stack gas scrubbers that require additional fuel.

An alternative for using coal with high sulfur content is to convert it to liquid or gaseous fuel, and simultaneously remove the sulfur.

About 30 to 40 percent of the energy content of coal is lost in such conversion processes. In addition to direct effects there are some important potential indirect effects on the choices of fuel resource utilization. For example, severe restrictions on particulate and sulfur dioxide emissions, enforced before the required technology is proven, could affect choices regarding coal utilization with long-term implications. These consequences should be foreseen and clearly understood as part of the decisions as to how much and how fast regulation is applied. Strip mining regulations on coal production are expected to add only a very small amount to the price of coal. However, the imposition of strip mine regulations, beginning at the same time as air pollution standards that impact strongly on coal use could result in retarded development of coal resources. It is clear that environmental regulation decisions should be made henceforth with due consideration given to the impacts on energy policy and vice versa.

1-3 THE NEED FOR ENERGY POLICY

The effects of the Arab oil boycott made it very clear that the U.S. needs to formulate national energy policy which will assure the reliability of future energy sources. The need is now compounded because of the expectation of new policy and the uncertainty as to what the policy will be. Refinery development is presently retarded because of uncertainty whether Project Independence will result in less foreign crude oil to be refined. Policy will certainly affect expectations about future prices. There is some hesitancy to develop higher cost alternative fuels such as oil from shale and oil and gas from coal until there is a clear basis for predicting future prices. As a result there is considerable, justifiable pressure to formulate a general energy policy as rapidly as possible. At the same time energy supply has sufficient importance for economic stability to require a rational, well-founded policy. There will be a requirement for sufficient time to determine alternatives, carefully assess their requirements and consequences, extract from the process a satisfactory policy, and determine the best means for implementation. Some delay will be well worth the temporary uncertainty.

The rest of this report is devoted to describing the systems approach to the energy problem. It is the feeling of the study group that this powerful tool has an important role to play in developing the information necessary for a rational debate on a national energy policy. In the next three chapters a method of assessing alternative energy futures is developed. In the remainder of the report this method is applied to determine the requirements and impacts associated with two proposed energy futures.

CHAPTER 2. SYSTEMS APPROACH

The methodology for the study is described in this section. Although the purpose of this study is to develop a method specifically for energy assessment and to apply it to several examples, it is felt that it is important to first consider the general features of the two concepts upon which the methodology is based, namely, the systems approach and technology assessment. Chapters 2 and 3 deal with a brief description of the methodology of the systems approach and technology assessment. The application of these methodologies to the problem of assessing energy futures is discussed in Chapter 4.

2-1 INTRODUCTION

The U. S. energy system is extremely complex. Not only does it involve many technical aspects, but also it is deeply intertwined with social, environmental and political factors. Because of this complexity traditional methods of analysis which focus on only one aspect of the energy system have not proven to be satisfactory. On the other hand, the importance of energy to the functioning and maintenance of society demands that the complete energy system be well understood. This is necessary not only to understand its present operation, but more importantly, in order to plan for the type of energy future desired by society it is necessary to know what are the alternatives, their requirements and their impacts so that rational decisions can be made as to the socially most desirable alternative.

2-2 SYSTEMS APPROACH

The methodology and techniques which comprise the systems approach had their beginnings in the desire for better managerial and operations techniques during WW II. These ideas have been developed during the last 30 years into a powerful theoretical system capable of solving a wide variety of problems in science, technology, business and social science. It is not the purpose of this discussion to give a complete description of systems theory.* Therefore, areas such as control theory, information systems and mathematical techniques will not be considered. The emphasis will be on those elements which can be used for problem analysis and decision making.

*For a more complete description, see [Churchman-68], [Wagner-69] and [Aguilar-73].

The systems approach is designed to give a better understanding of a systems operation and the interrelationships among its elements. It is often of interest to go beyond an understanding of the present operation of the system to ask what will be the behavior of the system in the future if certain factors are altered or certain sequences of decisions are made. It is the use of systems analysis as a tool in the decision-making process which shall be emphasized here.

Decision making is usually divided into three types:

> Decision making under certainty: This occurs in systems where the probability of the occurrence of events is known to be one;
>
> Decision making under risk: This occurs in systems where the probability of occurrence of events is known, but may be less than one;
>
> Decision making under uncertainty: This occurs in systems where the probability of occurrence of events may be less than one and at least some of the probabilities are not known.

In real systems decision making is usually made under risk or uncertainty and as the system becomes more complex it is more likely that probabilities are less well known and that uncertainty increases. In the past this has led some decision makers to despair of ever being able to understand or control the complete system and, therefore, they often concentrated on control and optimization of a sub-system instead. Unfortunately, one of the lessons of the systems approach is that very seldom does the optimization of a sub-system coincide with the optimization of the overall system. In fact, more often the opposite occurs. The optimization of a sub-system tends to produce undesirable effects in the total system. There are many examples of this, but one of the more familiar ones is the automobile. The automobile optimizes the ability of an individual to travel freely over the earth's surface. However, if one considers the automobile as part of the larger social system, it is now well known that the optimization of the automobile has produced many undesirable effects such as pollution, congestion, death and injury, high energy consumption, etc. The usually deleterious effects of sub-system optimization cannot be overstressed. It has resulted in many of the social problems that are present today. The emphasis on consideration of the whole system is one of the basic characteristics of the systems approach.

A representation of the systems approach to a problem is shown schematically in Figure 2-1. The first step in understanding a system is to collect the available information about the system. This may range from library research to actual experimentation and may represent the aspect of the study which requires the largest amount of time and effort.

The next step is data analysis. This includes the usual sorts of statistical analysis, but, in addition, it is necessary to the greatest extent possible, to identify all of the variables necessary to describe the system. Once the variables have been identified, they should be

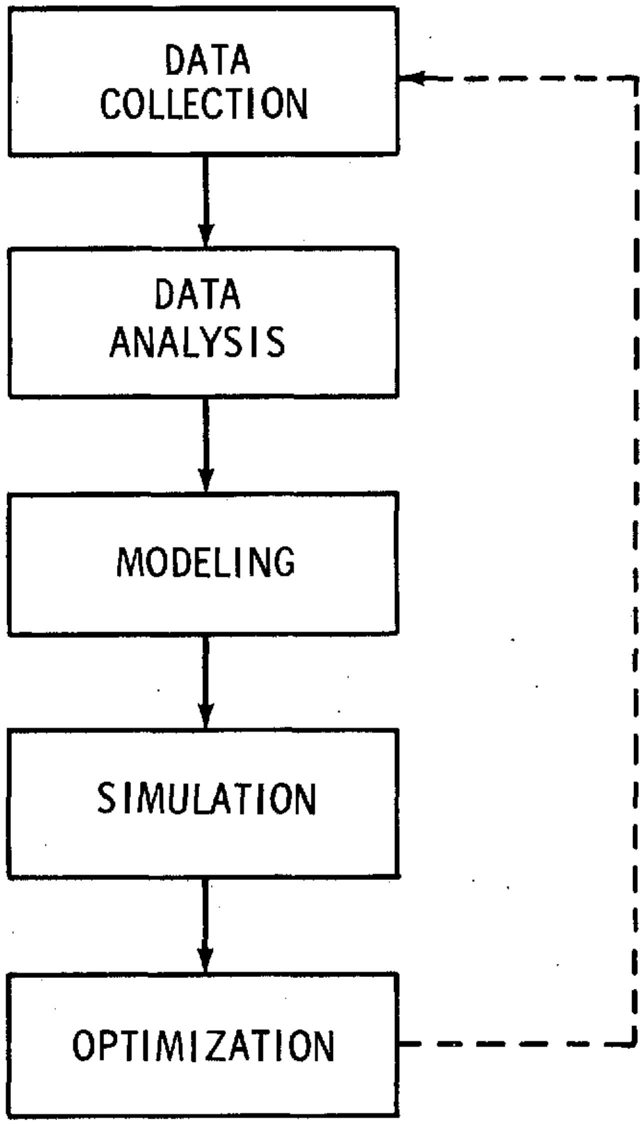


FIGURE 2-1 THE SYSTEMS PROCESS

classified as to their importance for the system, e.g., gasoline consumption is usually an important variable in the description of an automobile while color usually is not. An important variable in this context generally means that a change in the variable produces a significant change in the system. In theory, it would be desirable to consider all the variables in the system and their interrelations, but in practice this may be very difficult for systems in which there are many thousands of variables. Thus, in practice it is sometimes necessary to restrict the analysis to those variables which are most important for the description of the system.

The third step in the process is to construct a model which faithfully reproduces the actual relationships among the variables. This is often a mathematical or computer model, but it may be non-mathematical. Non-mathematical models may be described by tables, maps, graphs or words. Everyone operates in their day to day life on the basis of the non-mathematical model of the world they carry in their head. A model is always a simplification of the object it is designed to represent, if it weren't it would be merely a copy of the object. So the problem of modeling is to include all the variables and interactions which are important, i.e., which gives the model the same basic properties as the actual system without making the model so complicated and cumbersome that it becomes unusable. In addition to being sure that all the important variables are included in the model, it is equally important to include all of the interactions among those variables. This is often the most difficult part of model building since in practice many interactions are non-linear or involve feedback loops. However, it is just these non-linear and feedback relationships which are the most important aspect of the model since they are the things which will enable the model to reproduce the non-intuitive behavior that many complex, real systems exhibit and which is the aspect of the system which is often the least well understood.

Once the model has been developed the next step is to use the model for simulation. The purpose of simulation is to examine the behavior of the model under a wide range of variable values. The result is a wide range of behavior patterns by the model. It is also useful at this point to do a sensitivity analysis, i.e., examine how sensitive the output of the model is to small changes in the variables. This analysis may disclose that a variable whose importance was previously underestimated turns out to play an essential role in the model. If this occurs it may be necessary to return to the beginning to gather more data concerning that variable and to perform additional analysis in order to better understand its role in the model. From the point of view of the decision maker, simulation is very important since it enables him to ask what if? The consequences of many courses of action can be made explicit and can be more easily evaluated as to their requirements and impacts.

For some problems, it may not be necessary to proceed past the simulation stage, but usually there is a desire to find some optimum behavior of the system. If the optimization problem can be formulated mathematically, there are a number of techniques such as linear programming [Wagner-69] which can usually be used to find a solution. If the optimization problem is not formulated mathematically, it is still often desirable to find a "best" solution to the problem. "Best" means one of the possible solutions which also satisfies a given set of criteria such as low economic or environmental cost. Thus, a decision maker can choose from the many

alternatives generated by the simulation the one which best meets the criteria that he has established.

It may turn out that the optimal solution of the model is not acceptable because of a failure to satisfy an exogenous constraint. In this case it may be satisfactory to use a near optimal solution. If it is not, then the process must be repeated. Another reason for performing another iteration is that the results may indicate that the initial goal or problem statement was not what was really desired and that a modification has to be made in the goal or problem statements. A third reason for iteration is that the initial data base or analysis may have been inadequate. Whatever the reason, the process may be repeated as many times as necessary to obtain a satisfactory result.

There is no single widely accepted formulation of the systems approach. An analysis of the various formulations and their strengths and weaknesses is beyond the scope of this report. However, one other formulation will be presented which is especially useful in the actual design of a project [Vachon-74]. The relationship between the elements of the method is shown in Figure 2-2. The process indicated in the diagram can be divided into four phases:

Phase I - The definition of the objective;

Phase II - The establishment of the requirements necessary to meet the objectives;

Phase III - Determination of possible alternatives to the requirements;

Phase IV - Tradeoff or cost/benefit analysis to determine the final result consistent with the criteria.

The advantage of this representation is that it allows each of the phases to be considered as a separate sub-system study. Thus, to obtain the objective, it may be necessary to go through a procedure of the same form as in Figure 2-2, i.e., the objective of the sub-system study would be to define an objective for the primary study, then produce the requirements necessary to find such an objective, seek the alternatives to these requirements and the tradeoffs and criteria. The result would be the objective which is then fed back to the primary study to end Phase I.

Phase II can also be considered a sub-system study whose objective is to determine the requirements necessary to meet the objective of the primary study. Similarly, the process can be repeated for Phase III and Phase IV. If the system is very complex, it may be useful to increase the resolution by breaking each sub-system study down into four sub-sub-system studies. This breakdown can be continued if necessary to the point at which each piece becomes tractable. (See Figure 2-3)

In Phase IV, there may be a return to the tradeoff section due to the availability of new information or the realization that the emerging result is not, after all, the one that was really desired. If none of the results

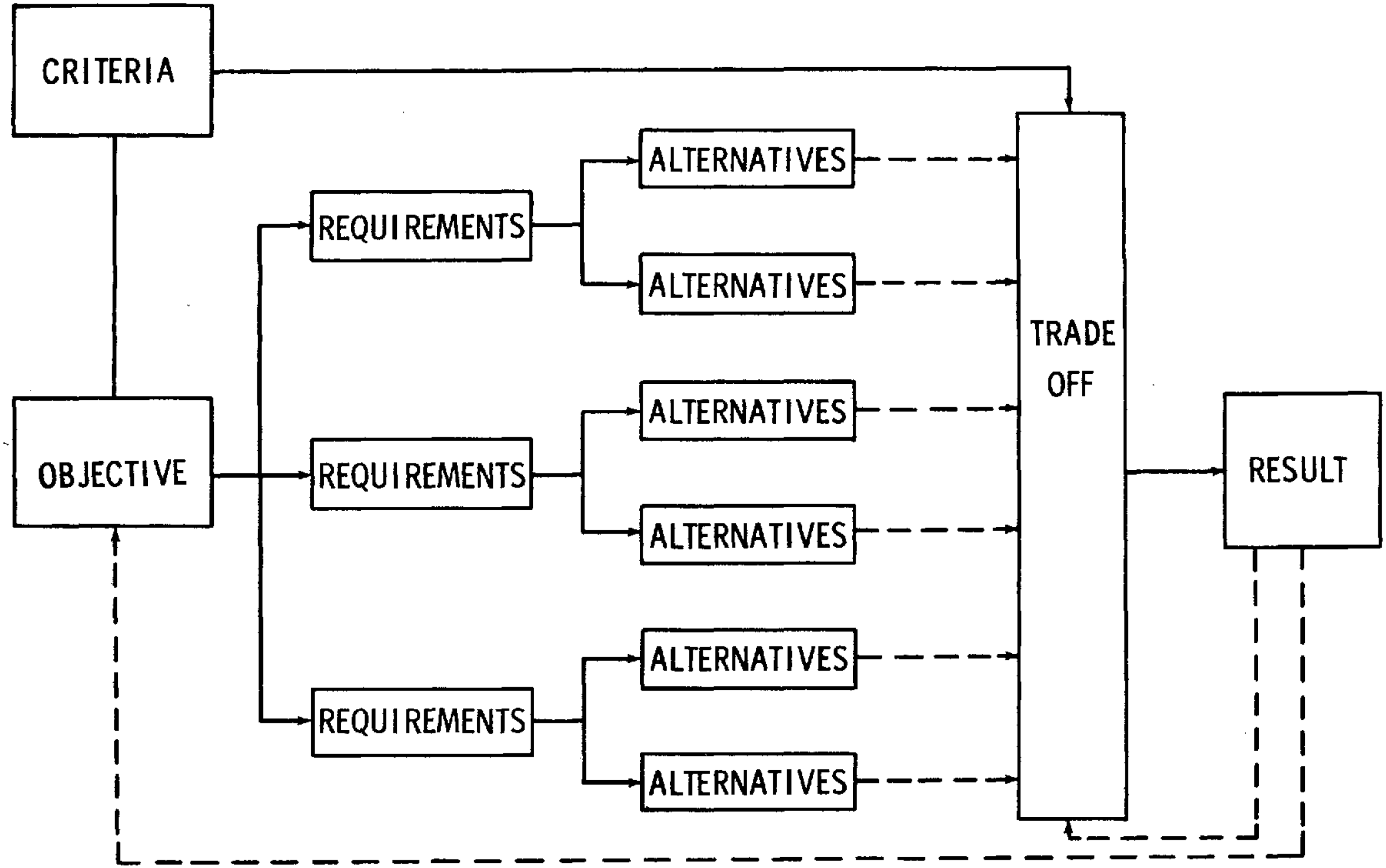


FIGURE 2-2 THE SYSTEMS APPROACH SCHEME

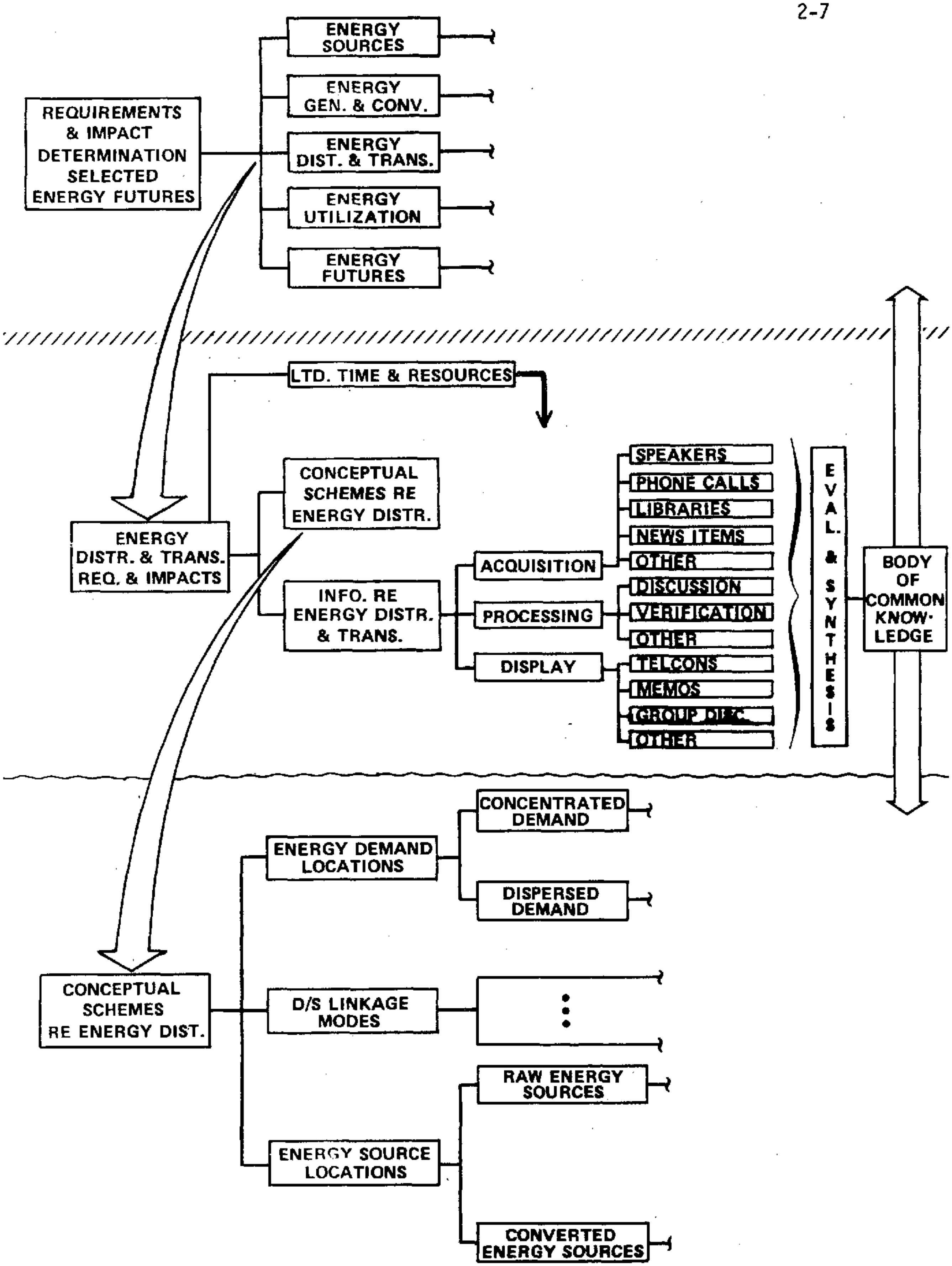


FIGURE 2-3 EXAMPLE OF THE SUB-SYSTEM BREAKDOWN PROCESS

is satisfactory, then it is necessary to return to the beginning to modify the objective and repeat the whole process again with the new objective.

This study has been designed using the procedure indicated in Figure 4-1. The details of the study organization are given in Appendix G.

In summary, this chapter has reviewed some of the elements of systems methodology which have proven useful in this study. The systems approach emphasizes a holistic view of problem solving. It provides a way to find a best or near best solution to a problem consistent with a given set of constraints. It can give decision makers information on the consequences associated with multiple alternatives and, therefore, provides a tool for better decision making. The application of these ideas to the U. S. energy system is considered in Chapter 4.

CHAPTER 3. TECHNOLOGY ASSESSMENT

This chapter will provide a brief overview of the process of technology assessment (called in some quarters, technological assessment). The relationship of technology assessment to the systems approach will also be discussed. These two methodological schemes provide a modus operandi for complex problem solving.

3-1 SOME DEFINITIONS OF TECHNOLOGY ASSESSMENT

Technology Assessment (TA) is a new field and has been defined in several ways. Some definitions from well-known TA practitioners and proponents are:

> identifying the potentials of applied research and technology and
> promoting ways and means to accomplish their transfer into practical use, and
> identifying the undesirable by-products and side effects of such applied research and technology in advance of their crystallization and
> informing the public of their potential in order that appropriate steps may be taken to eliminate or minimize them. [Daddario-67; emphasis added.]

> technology assessment may be defined as policy studies examining the fullest range of impact of the introduction of a new technology or the expansion of a present technology in new or different ways. [Coates-74]

> a systematic planning and forecasting process that delineates options and costs--economic, environmental, and social--that are both external and internal to the program or product in question, with special focus on technology related "bad" as well as "good" effects. [Strasser-72]

In discussing technology assessment, one should distinguish between those definitions that pertain to the TA process itself and those definitions that prescribe some governmental TA activity (i.e., that provide a mission statement for some agency, office, or board). Prominent definitions of TA tend to reflect the governmental-role perspective.

It is important to note that technology assessment is neither "technology arrestment" nor technology apologetics. Technology assess-

ment is simply an approach to make sure the consequences are understood when it comes to using science and technology. Further, in speaking of technology the intent is to include both hard and soft technology. An example of hard energy technology is the combustion of coal to produce steam for the generation of electrical energy. An example of a soft technology in the energy area is the federal taxing policies and procedures such as the oil depletion allowance.

3-2 HOW TA SHOULD BE DONE

Figure 3-1 displays a frequently cited roster of the major steps in the TA process. There are many differing views on a TA study's end product and the governmental mechanisms for carrying out TA investigations. Here are some of those views:

> Establish a Technology Assessment Board "to provide a method for identifying, assessing, publicizing, and dealing with the implications and effects of applied research and technology". [Daddario-67]
>
> TA should "clarify the political choices rather than come up with a final answer". [Brooks and Bowers-72]
>
> TA functions should be done by a "constellation of organizations strategically placed in government." [Brooks and Bowers-72]
>
> Assessments should be made by expert task forces in a neutral, nonpolitical environment. [NAE-69]
>
> Use assessments and counterassessments in an adversary proceeding process. [Folk-69]
>
> Establish a "devil's advocate agency" to expose and bring into the choice process the negative aspects of a technology. Such an agency should conclude what government's role with respect to technology should be. [Green-69]

The Congress has implemented Daddario's proposals by the creation of the Office of Technology Assessment (OTA) to serve its need for an independent source of technology evaluations. The OTA, at the time of this writing, is in its formative stages.

Some additional indications of the acceptance that TA has attained are:

> the formation of a professional association--The International Society for Technology Assessment;
>
> the publication of a journal--<u>Technology Assessment</u>;
>
> the strong foreign interest in TA; see[Hetman-73].

STEP 1	DEFINE THE ASSESSMENT TASK DISCUSS RELEVANT ISSUES AND ANY MAJOR PROBLEMS ESTABLISH SCOPE (BREADTH AND DEPTH) OF INQUIRY DEVELOP PROJECT GROUND RULES
STEP 2	DESCRIBE RELEVANT TECHNOLOGIES DESCRIBE MAJOR TECHNOLOGY BEING ASSESSED DESCRIBE OTHER TECHNOLOGIES SUPPORTING THE MAJOR TECHNOLOGY DESCRIBE TECHNOLOGIES COMPETITIVE TO THE MAJOR AND SUPPORTING TECHNOLOGIES
STEP 3	DEVELOP STATE-OF-SOCIETY ASSUMPTIONS IDENTIFY AND DESCRIBE MAJOR NONTECHNOLOGICAL FACTORS INFLUENCING THE APPLICATION OF THE RELEVANT TECHNOLOGIES
STEP 4	IDENTIFY IMPACT AREAS ASCERTAIN THOSE SOCIETAL CHARACTERISTICS THAT WILL MOST BE MOST INFLUENCED BY THE APPLICATION OF THE ASSESSED TECHNOLOGY
STEP 5	MAKE PRELIMINARY IMPACT ANALYSIS TRACE AND INTEGRATE THE PROCESS BY WHICH THE ASSESSED TECHNOLOGY MAKES ITS SOCIETAL INFLUENCE FELT
STEP 6	IDENTIFY POSSIBLE ACTION OPTIONS DEVELOP AND ANALYZE VARIOUS PROGRAMS FOR OBTAINING MAXIMUM PUBLIC ADVANTAGE FROM THE ASSESSED TECHNOLOGIES
STEP 7	COMPLETE IMPACT ANALYSIS ANALYZE THE DEGREE TO WHICH EACH ACTION OPTION WOULD ALTER THE SPECIFIC SOCIETAL IMPACTS OF THE ASSESSED TECHNOLOGY DISCUSSED IN STEP 5

FIGURE 3-1 SEVEN MAJOR STEPS IN MAKING A TECHNOLOGY ASSESSMENT [Jones-71]

3-3 CRITICISMS OF TECHNOLOGY ASSESSMENT

Much of the criticism concerning TA derives from studies that were labeled or came to be labeled as TA work, but were not as comprehensive as TA proponents felt they should have been. In some cases, only first-order benefits and costs were examined and higher-order effects were neglected.

Critics have pointed out that most TA studies are performed by experts in the technological area involved and that these experts tend to be biased and acceptive of current institutional arrangements. While it is true that value-free studies of any kind are almost impossible to produce, it is clear that a TA team should not be comprised completely of those with vested interests. This view is reflected in Green's and Folk's suggestions cited earlier.

Finally, from a more philosophic point of view, TA can be viewed (and indeed is viewed by some) as a serious attempt by political institutions to control and manage technology. If this is so then the process could foster centralized state planning and the evolution of a meritocratic social structure. The issue of centralized state vs. decentralized private planning goes beyond technology and promises to loom larger as a societal issue.

3-4 COMPARING TA AND THE SYSTEMS APPROACH

To review the systems approach is an <u>organized</u>, <u>consistent</u> way of tackling problems that emphasizes the systems nature of things, i.e, an emphasis on the interactions and interdependencies among a set of elements. Therefore, careful delineation of the following is stressed in the systems approach:

Objectives, goals, purposes;

Constraints and controls;

Necessary requirements for meeting objectives;

Alternative ways of meeting requirements;

Criteria for evaluating and comparing alternatives;

Tradeoffs involved in synthesizing the alternatives into a form that enables attainment of the objectives.

It is the requirement for taking a comprehensive, analytical view that constitutes the kinship of the systems approach and technology assessment methodologies. The systems approach has been diagrammed in Figure 2-2. The process of TA can be diagrammed in a similar form as is shown in Figure 3-2. The numbers in the corners of the boxes refer to the step numbers in Figure 3-1. The similarity of Figures 2-2 and 3-2 underline the basic similarity of approach of the two methodologies.

TECHNOLOGY ASSESSMENT

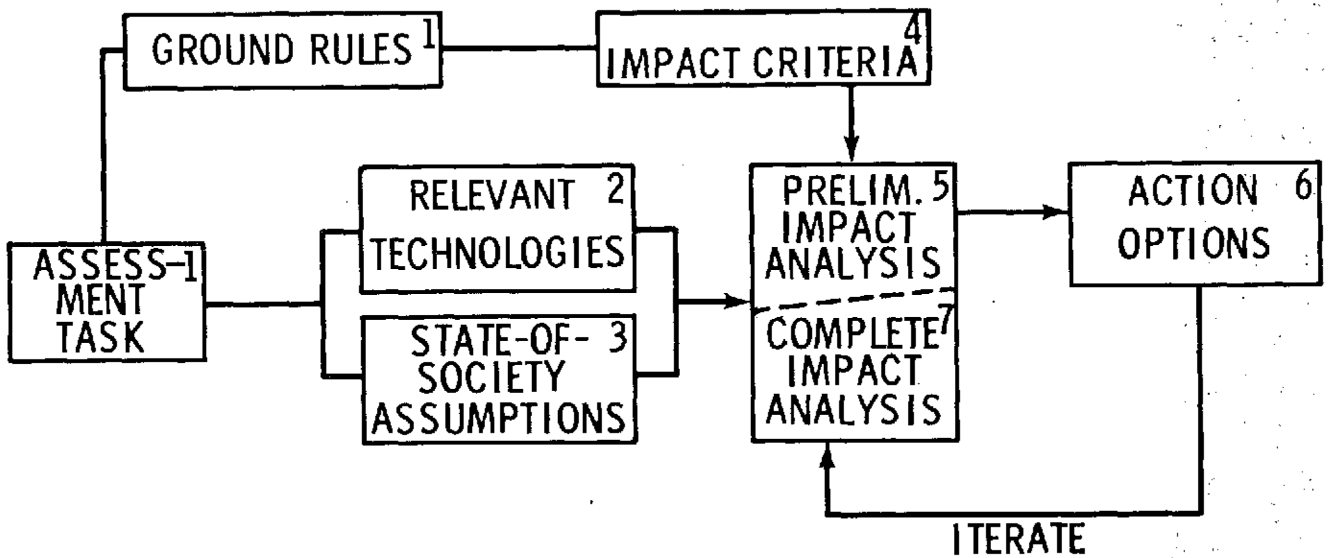


FIGURE 3-2 FLOW CHART OF THE ASSESSMENT PROCESS

Of course, what is important here is not the particular boxes and their labels but rather the underlying mental process, which stresses the synoptic view and a willingness to be explicit and to go beyond the obvious first-order effects in an analysis.

The systems approach and technology assessment clearly are compatible and mutually reinforcing methodologies for tackling large-scale, complex socio-technical problems. Concepts from both of these methodologies have been used in this study to develop an assessment method to analyze energy systems. The details of this assessment technique are given in the next chapter.

CHAPTER 4. ENERGY SYSTEM ASSESSMENT

The methodology of this study is developed in this chapter. It is based on those elements of the systems approach and technology assessment which were discussed in Chapters 1 and 2 applied to the problem of developing the requirements and the impacts of those requirements necessary for the attainment of alternate energy futures. The methodology is considered to have general applicability to the problem of assessing energy futures. An example of its application to three particular cases is considered in Section II. Other investigators are encouraged to test the methodology by applying it to other cases.

4-1 INTRODUCTION

The basic energy future assessment process is shown in FIGURE 4-1. Each of the criteria, requirement and tradeoff boxes is discussed in a separate section in the remainder of this chapter. Note that the objective is not to reach a conclusion, but to produce a set of requirements and impacts for each of the alternate paths into the future that have been selected for consideration. So the end result of the process is not to make recommendations or decisions, but to provide better information as to alternatives and their consequences so that decision makers can make better decisions. The underlying assumption of the whole process is that rational decision making requires the best possible information concerning alternate choices. It should also be noted that in this context decision maker is used in its widest sense to include any person in a society who is involved in any way in the decision making process. This includes citizens as well as their elected governmental representatives.

4-2. CONSTRAINTS AND CRITERIA

Constraints and criteria are a list of limiting statements which have been accepted by the assessment group for philosophical or other reasons, but are not embodied in the objective of the study. One of the advantages of the systems approach is that this effort makes explicit those presuppositions and basis of the investigators which might affect the study, as opposed to specific judgement statements needed to initiate the assessment process. Another set of conditions which need to be explicated are those constraints which may be important for the study, but which are not stated in the objective. In the case of an energy planning study these might include conditions such as low environmental impact, minimum reliance on imported oil or maximum development of solar energy utilization.

To further illustrate the criteria and constraints for this study are

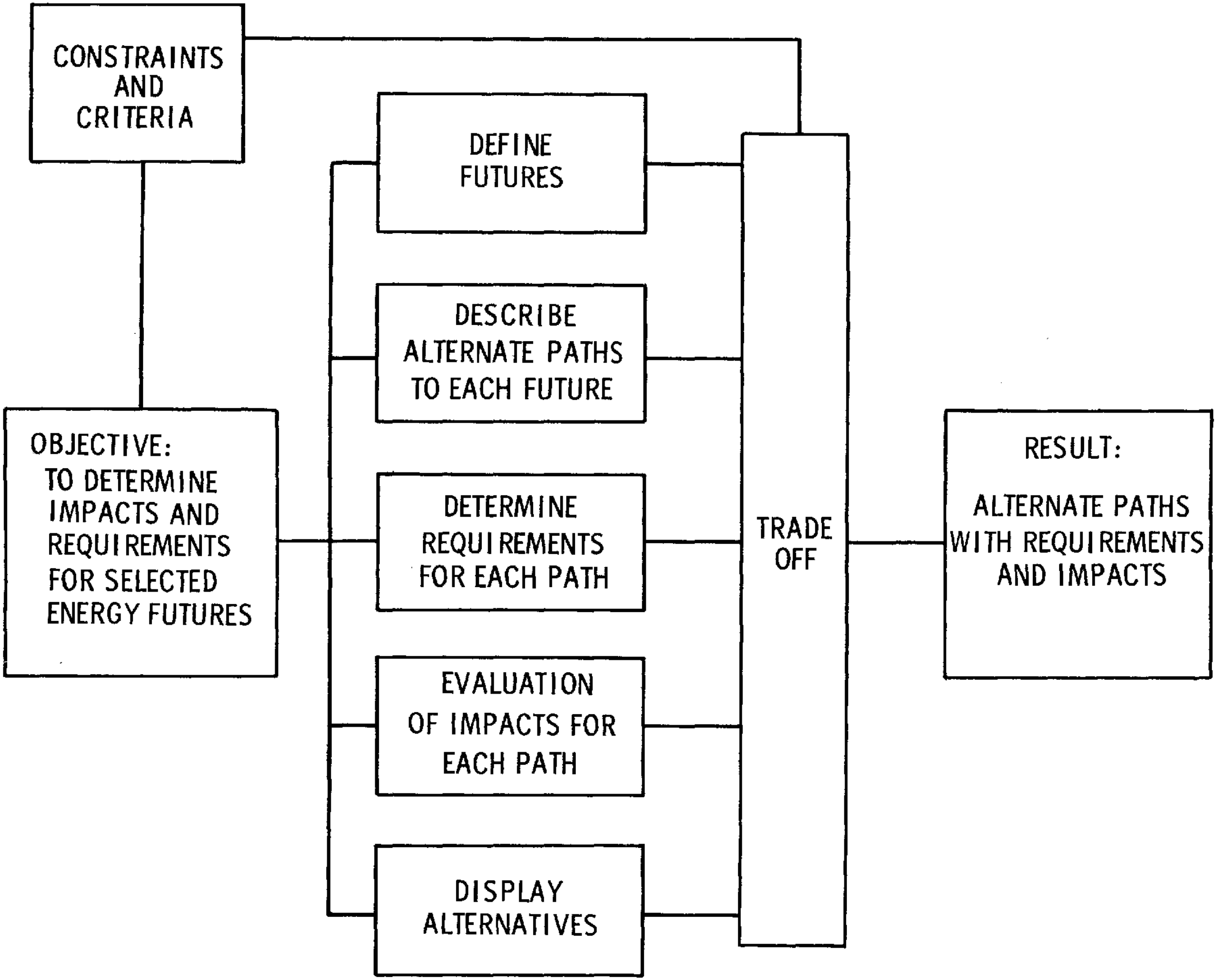


FIGURE 4-1 DIAGRAM OF ASSESSMENT PROCEDURE

listed by area of concern:

Selection of energy future scenarios

Timeliness, e.g., post oil embargo formulation is desirable.

Availability of detailed information about the scenarios is necessary.

Only scenarios which are already well analyzed by their authors for different purposes or with different methodologies that this group proposes are to be considered.

Scenarios which have attained wide circulation and visibility are leading candidates.

Value judgments

The satisfaction of energy demand is weighed against considerations of well-known negative impacts such as SO_x emissions or plutonium hazards.

Priority is given to avoiding a balance of payments deficit.

The future must utilize energy more effectively (at least in a technical sense) than it does today.

The future should at least maintain the present standard of living.

Analysis of the selected futures must have the potential for giving the summer study real value in the dialogues occurring now among policy makers.

No major social dislocations will take place in the period under consideration.

Economic aspects of the future

An analysis of economic effects and requirements for implementation is needed.

Economic well-being does not necessarily imply growth.

Major economic restructuring is ruled out by presuming essentially a continuation of the present economy.

Voluntary, market controlled, profit producing methods form the economic base.

Economic changes should be orderly.

Large segments of the national economy and budgets are committed to other sectors of society.

Present economic constraints will delay any significant economic changes to a time beyond 1980.

Pricing should include all costs, i.e., externalities such as providing for the health and safety of mine workers.

Technological aspects of the future

Futures must be attainable.

Technology for the period under consideration will depend on present or medium term technology developments in the areas of fuels, generation and distribution with possibly some longer term developments in conversion and end use.

Future should be planned to leave several options open at the future point. This constraint places heavy reliance on the continued success of technology.

Future should accommodate speculative elements and long range impacts (health, environment) by periodic complete assessments prior to action phases. The future point itself should be considered an assessment point not a goal.

Future should minimize unnecessary technological obsolesence.

Future must consider impacts on and requirements of other major sectors such as public health and environment, aging of cities, and agriculture.

Considerable effort should be expended in improving large energy system reliability.

Scenario parameters

The future and paths considered must include analysis of the requirements for getting on the path, the effects of getting off the paths, and the effects of major elements of the energy industry embarking on paths different from the scenario.

The future point is determined in time by considering the limited flexibility of the near term and the appearance of major positive (e.g., fusion) and negative (e.g., environment) factors in the far term.

Energy consumption is assumed to grow no faster than historical growth.

A turn down in the energy consumption curve will provide more opportunity for reassessment and planned change.

The future point is considered to be the time for assessment prior to the "next" future, i.e., planning should be a continuous process. For this reason changes should have been in effect long enough prior to the future point that their impacts and benefits can be assessed.

Policy assumptions

Some form of explicit national energy policy is necessary.

National policy must be accompanied by long range planning studies.

National policy must make provisions for programs of a duration and complexity comparable to those of the Defense Department.

National policy, particularly in the adjustment period, must recognize the individual base building activities of the private entities in the energy industry.

National policy should contain provisions for insuring adequate energy supplies for national defense and foreign policy.

National policy should encourage the development of minimum cost, secure supplies of energy.

4-3 DEFINITION OF ENERGY FUTURES

The description of futures in general and energy futures in particular is often based on an extrapolation of present trends to the desired future date. Experience has shown that this type of extrapolation becomes more and more unreliable the further away the future point is. The major reason for this is that "surprises" occur which were not taken into account in the extrapolation. Such "surprises" take many forms such as revolutions, inventions, scientific discoveries and so on. Although there is no known way to anticipate all "surprises", other methods of future definition try to minimize their effect by anticipating at least the most probable ones.

It is the point of view of this study that rather than extrapolating the present to the future it is better to define the future on the basis of some acceptable set of criteria. The problem then becomes how to get to the desired future from the present. In section 4-4 the problem of choosing the various paths from the present to the desired future will be considered. In the rest of this section the problems associated with defining the future point will be explored.

There is a tendency in defining energy futures to characterize the future by just identifying the gross energy consumption. While this guarantees placing energy in the forefront, it is not the most logical procedure. A more logical method would be to identify the energy consumers and their energy related activities, yielding energy consumption as a requirement to sustain these activities. Energy sources and technologies are then the means to fulfill the

required energy consumption.

Energy Mix

In practice, however, an energy future is defined by the specification of the principal energy forms and the relative amounts of each needed to achieve a certain gross energy consumption. Specifying different energy forms in various amounts defines alternate futures. The influence of energy consumers and their energy related activities, as well as energy sources and technologies, are factored into the assessment of impact and requirements. This is accomplished by spelling out several other mixes in addition to the energy mix as part of the definition of the energy future. The slope of energy consumption is also included in the definition of an energy future.

Population Mix

Population mix is one of the required additional mixes. Breaking down the population by number, age, marital status, family size, location and education yields a mix which is very inflexible in the time frame from 1974 to 2000 (see section 1-3 of Appendix E for details). It has a long response time and slow response rate. Historical evidence shows that at least two generations are needed to change the whole population distribution. The most mobile parts of the population are generally the youngest people residing away from major cities. Since eighty percent of the population lives in urban-suburban areas [DOL-73], only small segments of the population are readily changeable. Also, only certain job types or industrial jobs are readily altered.

GNP Mix

Gross features of GNP are needed to assess an energy future. Specifically, the total amount of GNP and the per capita share are important. Projections such as given in "Alternative Futures and Environmental Quality" [EPA-73] are quite optimistic about increases in total GNP and per capita share. This will probably mean greatly expanded industrial energy consumption. In the past increases in per capita energy consumption and GNP have been closely correlated. It is not clear, however, that this correlation would be so close in an economy with low economic growth. In so far as industry determines the number and level of jobs available to the population, it greatly controls not only its own energy requirements, but also the energy requirements and lifestyles of its employees and their families. The extreme case is that of too much energy being consumed to produce more energy generating equipment. This is undesirable in that not enough energy is left to foster industrial expansion. Without industrial expansion, there is no market for the increased level of energy production from the additional generating equipment. Moreover, to attain a higher per capita energy consumption requires an increase in productivity. For industry to increase productivity, it must have energy available to build equipment to aid its workers. In proposals for ZEG little consideration has been given to the problem of disposable income in a product limited economy.

In addition to revealing any disproportionate share of end use energy consumption by the energy production sector the GNP mix reveals whether or not the

products of industry are commensurate with the specified energy consumption. In addition to basic commodities, inventories are needed of staple products which consume energy. For example, air conditioners are not staple products but automobiles are. The auto industry is presently the largest single industry in the U.S. directly responsible for end use energy consumption. It may be the product in GNP most sensitive to changes in energy form and supply [Teague-73, Ford-74].

Competition Mix

From historical evidence, a major influence on the energy future will be competition within the energy industry for shares of the overall growth. The growth of any one component of a fuels mix at some future point assures immediate growth for current producers of that component. More effort and resources must be mobilized to prolong growth than to establish the original growth base. Base building, however, will be an allocation problem in low growth scenarios. At any time, the surplus of funds available to promote this mobilization is very limited. For example, Chase Manhattan's estimates [CMB-73] of worldwide capital requirements of the petroleum industry are $600 billion for the decade 1975 to 1985. This will come from three sources: borrowed capital and capital recovery, accounting for approximately 50 percent, and net profits for the remainder. Net profits would have to grow at an annual average rate of 18 percent, double the historic rate, to meet this requirement. Moreover, these estimates were made at a time when the prime interest rate was 9 percent and before the oil embargo. The success of particular energy producers in attracting borrowed capital will largely influence their growth and the availability of specific energy forms.

Crucial to an industry's ability to attract growth capital is its record of past performance. If history is followed, capital will flow to industries with good returns on investment and good growth potential. The energy industry sector which will have the best ability to attract capital will be one which can develop the best resource base and manufacturing, supply and auxiliary industries. The pre-exponential factor in a growth curve, the base for growth, will greatly influence the growth rate. This is a reason for the nuclear industry's haste to establish a base from which to grow.

Conservation Mix

Finally, conservation will probably be a significant element in energy futures. There are three senses in which conservation can affect the form and amount of energy use: reduced consumption, increased efficiency and delayed consumption.

Reduced consumption may occur either voluntarily or by mandate. Voluntary reduction is not satisfactory in the long run because it tends impacts non-uniformily on the conscientious and the unscrupulous. In either case reduced consumption over any extended period will result in changes in life-style and may result in a lowering of standard of living. Reduced consumption may be instituted even if supplies are available in order to extend their lifetime. A more typical case occurs when the reduced consumption is forced by immediate shortages in supply. Designers of scenarios have assumed no shortages, assuming that their energy allotments are both met by the suppliers and sufficient for the consumers.

Increased efficiency is a technological route to decreased consumption. Historically industrial processes were often designed with little regard to energy efficiency because of the abundant supply of cheap energy. It is expected that in the future concern for the most efficient energy use in all areas of technology will produce considerable energy conservation which in turn will lower the pressure on supply.

The third means of conservation, delayed consumption, implies a refusal to develop known reserves or cutting off further exploration with the object of saving the resource for an indefinite, long period. No currently available scenario suggests this practice even under zero growth of economy, energy consumption or population. It should be noted that conservation does not automatically guarantee an overall reduction in consumption since savings in one area may be used in another unless there is a reduction in total demand.

Summary

In summary, an energy future consists of the specification of the principal energy forms and relative amounts of each needed to achieve a certain gross energy consumption. Sufficient detail of the population mix is required to determine compatibility with the energy consumption requirements. GNP mix is needed to determine if disproportionate shares of the GNP are being used by the energy industry. The competition mix within the energy industry yields a picture of the reasonableness of the energy mix. Finally, the conservation mix determines demands on consumers and technology implied in the energy future.

4-4 ALTERNATE PATHS

A central feature of the methodology developed herein is to view the present from a defined future point with the object of determining alternate paths which connect that future to the present. There are obviously an infinite number of paths which connect two points. In practice, however, there are usually only a few paths which are sufficiently different from one another to be of interest. The requirement that the path match both the present and the future in magnitude and slope restricts considerably the acceptable paths. Additional requirements of lack of discontinuity and smooth behavior restrict the available number even further. The requirement for smooth behavior is equivalent to assuming that there will be no catastrophic events along the path which would produce radical changes in consumption or rate of consumption. This does not mean that radical changes or other "surprises" are not likely to occur, only that they are difficult to anticipate. The cases with smooth behavior should be analyzed first since they are the least complicated. They can then be used as a basis for analyzing what would happen if major changes are introduced.

Four examples of alternate paths between the present and a future point are shown in Figure 4-2. Growth along path 1 is exponential and it reaches

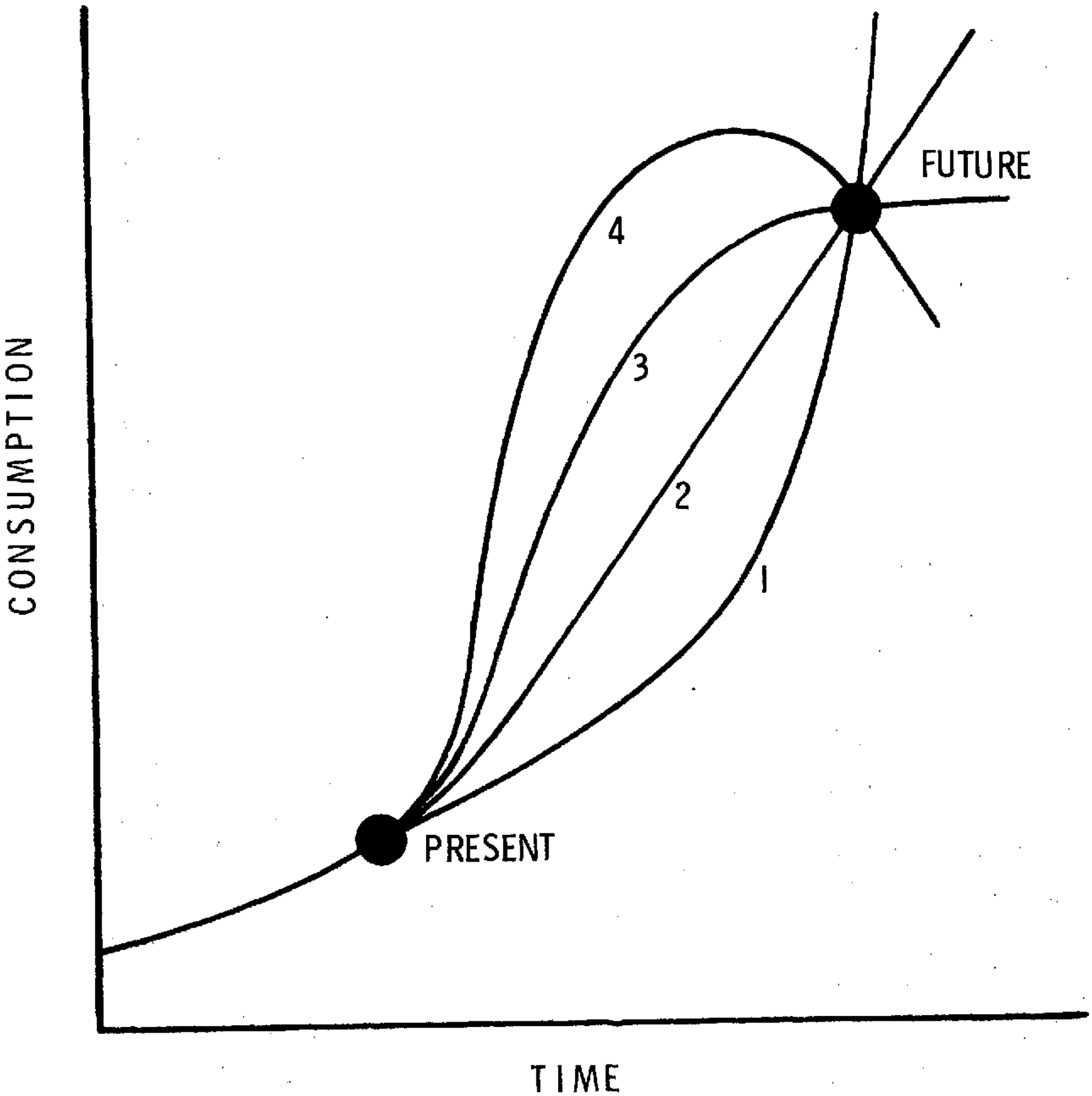


FIGURE 4-2 EXAMPLES OF ALTERNATE PATHS BETWEEN THE PRESENT AND A FUTURE

the future with a high and increasing slope. Growth along path 2 is linear and it reaches the future with a large, but constant slope. Growth along path 3 is initially exponential, but it has a turnover before it reaches the future and, therefore,the slope at the future is low or zero. Growth along path 4 is also initially exponential, with a very high rate, but it suffers a decline before it reaches the future and, therefore, reaches the future with a negative slope. These four basic types are the ones which are both sufficiently different from one another and also satisfy the conditions of continuity and smoothness.

There is however, more to the definition of a path than just total consumption and rate of consumption. The discussion of the elements needed to define a path parallels the previous discussion of the elements of a future point. Initially the path is defined in terms of the variation in time of its macroscopic properties:

Total consumption

Total consumption rate of change

Total population and economic indicators

Total sector requirements.

These and other gross features of the path do not pretend to detail a complete United States economy. Under the basic assumptions described in section 4-2 a limited number of macroscopic factors and technological model inputs are considered as sufficient to describe the paths.

Changing Macroscopic Properties

Certain statements concerning the requirements for changing a baseline path i.e., the present path over to one of different macroscopic properties can be made. In all the scenarios considered in this study the baseline path is exponential. Recognizing all of the difficulties associated with extrapolating exponential growth indefinitely [Meadows - 72], extrapolation of historical exponential growth is still a possible path to some futures. All changes in this historical baseline scenario must compete against the large momentum of the historical growth. Whether this momentum remains real into the future is not at issue. Whether real or fictitious this momentum serves to define the strength and rate of growth of the changes required to divert the baseline scenario onto the path of interest. So much of what is currently offered as knowledge about the U.S. energy future is summarized in compounded (exponential) growth factors that we retain the language for ease of comparison.

Exponential growth curves are characterized by ever increasing slope. To alter an exponential curve to one of smaller growth rate introduces a period of decreasing slope. The change to produce this transition must be itself an exponentially growing quantity. This greatly limits the physical character of the change since as long as the historical pressure for growth remains the change factor must grow almost as fast. Thus, change factors which saturate or reach an upper limit of effectiveness can not produce a transition from one exponential path to another indefinitely. The suggestion is that no change factor has indefinite

worth without an attack on the fundamental determinants of the historical growth rate. Any scenario which tries to alter the historical pattern without attacking the central factors of growth must be considered as transitional, not leading to a future point with built in ability to control the growth beyond the future point.

A characteristic of growth scenarios with simple gross expansion is that the individual components (of the fuel mix for example) are modeled to grow exponentially themselves. This is unrealistic since it neglects the distinct differences fuel to fuel in positive growth factors such as expanding known deposits and the negative factors such as resource exhaustion rates. Introduction of a saturation or contraction of a major component of the fuel mix puts extra pressure on the other components of the mix. Thus, a simple mixture of simple exponentials ignores even the rudiments of the individual fuel supply interactions.

One important class of alternate paths to be considered for this transition period is paths which reach the future points with much lower slope than in the original scenarios. To achieve a given level of consumption with a low slope in the late portions requires considerable overshoot and high growth in the early portions. It is unlikely that this behavior can be realized by only one or two fuels since this would require additional rapid immediate expansion of the producing, conversion, and marketing industries followed by rapid contraction. The time remaining till the year 2000 is shorter than most design lifetimes of major plants and therefore, it would be impossible to realize a sufficient return on investment. Thus, it is not likely that such investments would be made. The contraction period of a major fuel might be brought on by resources exhaustion, but this does not alleviate the need to protect investments by substitution, e.g., synthetic gas or hydrogen or imports in place of natural gas. The brief discussion above shows the danger in deforming the gross features of a path with no considerations beyond consumption totals. While amortization considerations do not rule out this method of reducing growth at the future point they show two things:

> The period of slope reduction will be shorter as the slope at the future point is reduced.
>
> No single component of the energy industry will willingly bear the cost of the contraction losses.

This discussion also shows that the requirement for meeting a given energy total without capacity that can be turned off with little penalty substantially determines the intermediate values. The suggestion is that to achieve lower growth rate at a future point requires consideration of alternate paths containing periods of very rapid change over from high growth to low.

Planning and Preparation Periods

A further consequence of any class of paths which contain a turnover in slope or a turn up in slope is that a period of planning and preparation is necessary. One point of the philosophy in this study was that there be rational planning of events in the energy future and the path to that future. This means

that an important element of a definition of a path is the specification of the periods of planning for change and the periods for reassessing developments, successes, and failures. Schematically some time elements of a path are shown in Figure 4-3. The example in Figure 4-3 is for a turndown growth rate. No smooth curve constructed only from growth segments and transition sections can be guaranteed to be viable or even consistent with the details of the future point. Inputs are needed to help constrain the paths. These inputs are part of an iteration process. As the inputs are iterated with consideration of path requirements the flexibility of the path diminishes. Some constraints are already contained implicitly or explicitly in the philosophy statements:

> The period of adjustment is from 1974 to 1980 or 1982.
>
> The preparation period for the turnover is of the order of the lead-times for major plants and for the turnover of articles like automobiles and oil wells, i.e., approximately a decade.
>
> The duration of the turnover phase is governed by the difference between the time to prepare and the occurrence of the future point.

Thus, the temporal factors are already fairly detailed for this sort of turnover path.

The slopes at the present and future provide a further constraint on the path. In addition, the assumption that there will be no major dislocations in social, economic, political or institutional developments essentially eliminates abrupt fluctuations in the path. This does not mean, however, that there are no fluctuations in the components such as fuel mix that make up the path. The point is that components may change fairly rapidly, but that the sum of the components changes slowly. Whether or not a proposed path can actually be realized will depend on the ability of the society to move onto the new path in a short time (the initial period of the path is especially critical). Failure to make adequate initial decisions and actions may put a given path out of reach.

Figure 4-4 sketches how a rational planning process would proceed. This planning is for a path containing phases in energy development. The phases are of two kinds: decision and action. Neither of these is strictly a point in time, particularly the latter. The only type of action mentioned so far is the turnover period during which significant change in slope would be occurring. By implication the adjustment period contains some short term actions.

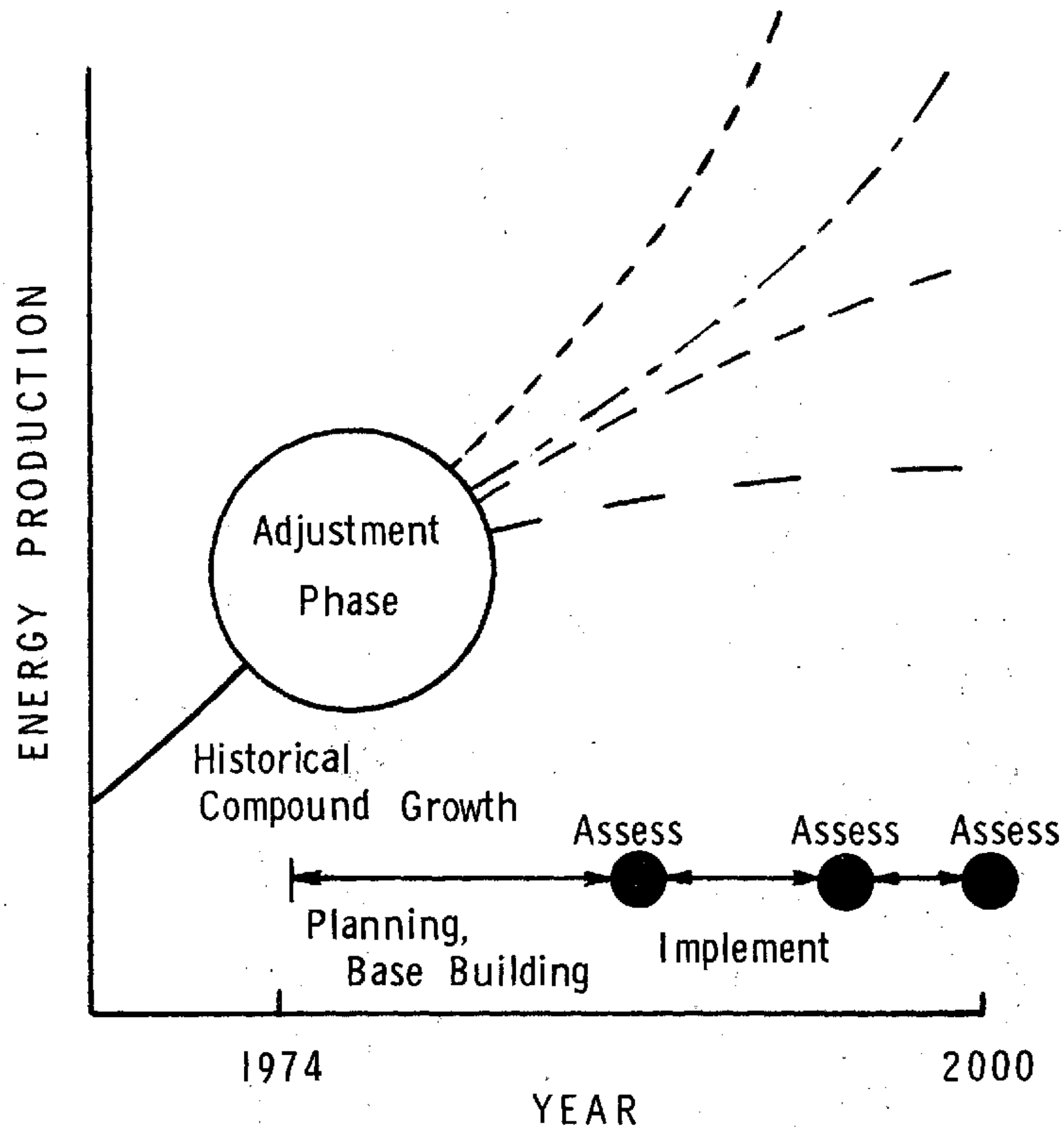


FIGURE 4-3 THE RATIONAL PLANNING SEQUENCE--AN ALTERNATIVE TO CRISIS PLANNING. THE PERIOD 1974-2000 IS SHORT ON THE SCALE OF PLANNING, BASE BUILDING, IMPLEMENTATION, AND ASSESSMENT PERIODS. THUS, THIS TRANSITION OF 25 YEARS CANNOT CONTAIN MORE THAN ONE OR TWO DECISION POINTS OF NATIONAL SCALE.

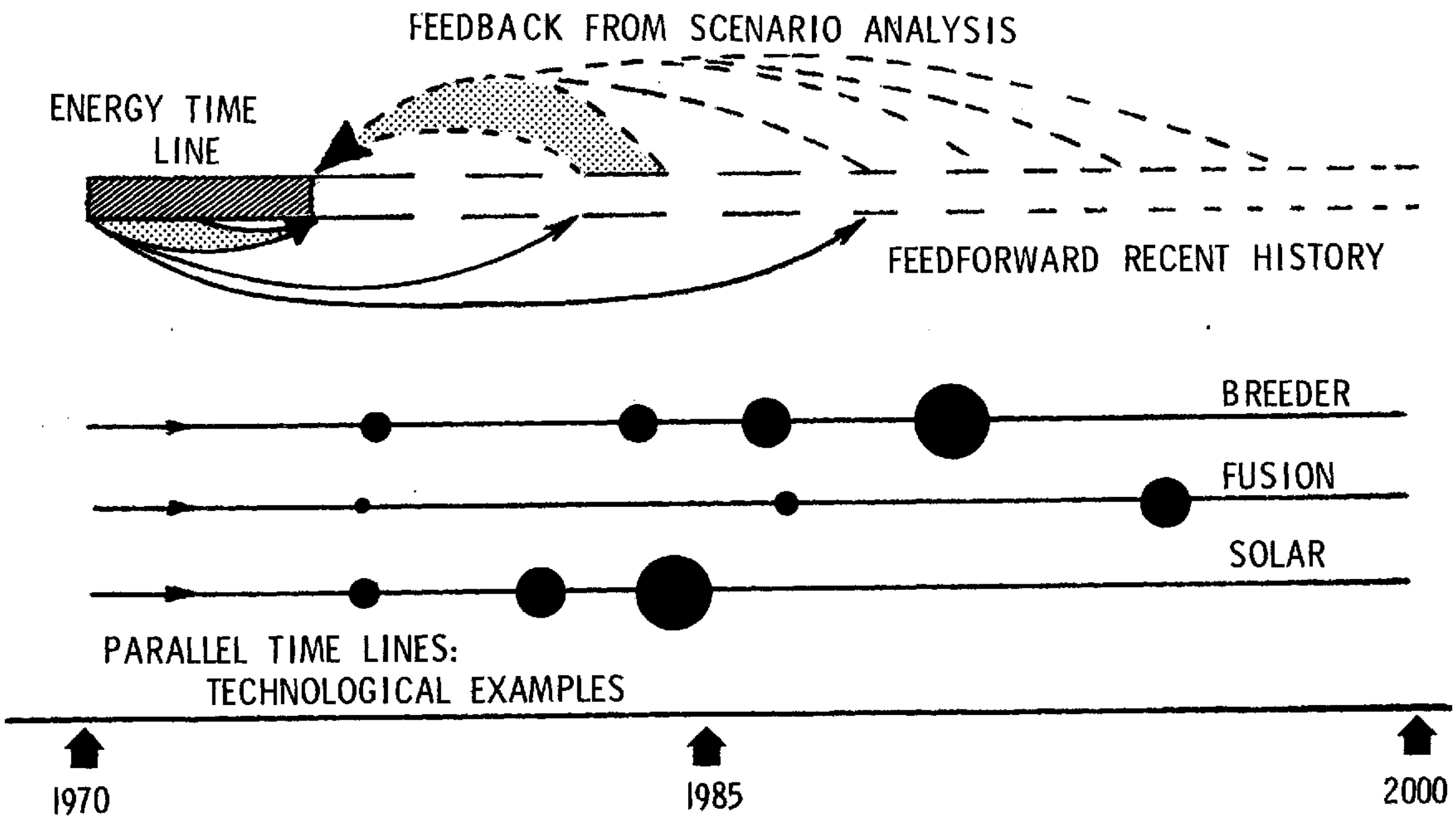


FIGURE 4-4 INFORMATION FLOW IN RATIONAL PLANNING. FEEDBACK AND FEEDFORWARD OF CORRECTING INFORMATION OCCURS BY SCENARIO ANALYSIS AND BY ASSESSMENT OF HISTORY, RESPECTIVELY. THESE STREAMS ARE WEAKENED BY INTERVENING TIME AND BY INCONSISTENCY IN POLICY. INFORMATION IS ALSO DERIVED FROM MANY PARALLEL TIME LINES. SOME TECHNOLOGICAL EXAMPLES ARE SHOWN WITH A SUGGESTION OF RELATIVE TIME AND RELATIVE CRITICALITY. THOSE PARALLEL LINES SHOWN ARE FUTURE SCENARIOS THEMSELVES.

Initial Conditions for Alternate Paths

The two basic parameters of a compound growth model are the rate of growth and the pre-exponential value (the principal). Some deductions on the size of competing rates were stated above. The other factor, the pre-exponential value is of fundamentally different character. Orderly growth assumes a base, an initial condition. Of the processes for establishing and maintaining the growth rate. The period of adjustment is the time for establishing the base for the changes to be implemented during the growth to the next phase. Similarly, the planning period prior to a phase like the turndown phase in Figure 4-3 contains the establishment of the base for the turndown operation. The reassessment point prior to the action phase would look at the completeness of the base of each alternative action and at the needs, benefits, and drawbacks before committing to the action phase. The assessment of this base for all relevant technologies is not possible at this time. Thus, scenarios dependent upon fusion or solar energy do not seem to be realistic at this time. There simply is no base for development of growth of these energy sources even though rather detailed accounts of the requirements and impacts can be made. Since their bases do not exist they have not been utilized in the description of alternate paths. It is not yet possible to examine their interactions with other fuels and other sectors of the economy.

The current period of adjustment to energy planning for the future is exactly the period in which a base for growth of new technologies must be established. One of the outputs of the methodology of alternate paths viewed from the future back is a detailed description of the base and the requirements for establishing this base. This idea of a base for growth of a new factor in energy development should be carefully distinguished from the requirements of rapid expansion of established factors. Presently, some initial proposals for establishing the base for new energy sources are being formulated. Work is proceeding in Congress to establish a base for the solar heating and solar heating and cooling industry by using federal influence and support to short circuit some obstacles to speculative industries. Other speculative technologies are also receiving this sort of help such as synthetic fuels, the breeder concept, and photovoltaic solar systems.

Summary

In summary, there are a large number of alternate paths between the present and any future point. The problem is to reduce the number to a few that are tractable for analysis. In the case of energy futures the number of paths can be greatly reduced by the requirements of continuity and smoothness. This, however, is not enough to ensure that the path is viable. Variations in parameters such as fuel mix, economic constraints, and other social factors must be considered. In the case where the path calls for the growth of a new technology the existence of a base upon which that growth can take place must be investigated. Once all of these factors have been considered there are usually only a few viable alternatives left for analysis. A description of the three paths considered in this study is given in Chapter 7.

4-5 PATH REQUIREMENTS

Once the various paths have been defined in terms of total consumption and fuel mix, the next step is to translate these definitions into numbers of power plants, oil wells, mines, etc. It has been found that it is easiest to first determine the unit requirements for the constituents of the path, for example, the capital, manpower and materials necessary to build a 1000 MWe nuclear power plant or to open a new 2,000,000 Ton per year coal mine. Once the number of facilities of each type is known for a given path, it is easy to sum up the necessary individual units to give the total capital, manpower and material requirements for the path. This assumes, or course, that the unit selected is typical (average).

It is, however, often of interest to look beyond the gross totals to try to uncover bottlenecks. For example, it has been found that in some instances the barrier to opening a new strip mine is the lack of draglines. Moreover, dragline production is already committed for three years in advance. Thus, even though the capital manpower and other materials are available it would take four to five years to start a new strip mine that uses a dragline because of the bottleneck in dragline production.

Similar bottlenecks may occur with other types of specialized equipment or some scarce materials. The requirement may be small in absolute value, but might represent an appreciable fraction of the total available amount.

The same situation may also occur in manpower where it may be possible to meet total manpower needs, but certain specialized skills may be lacking even though they are only needed in small absolute numbers.

Once bottlenecks are identified it may be possible to eliminate them by substitution of materials, governmental action, small changes in the path, or other actions. A recognition of the bottlenecks does give an indication of the difficulty in meeting the requirements of a given path.

The purpose of determining the path requirements is to be able to understand the total social commitment necessary to follow the indicated path. If the requirements are too great, then it may become apparent that, although initially attractive, the social cost of that path may be too high or the path would be impossible to follow without serious social dislocations. In either case a decision maker would justifiably reject the path as unfeasible.

The unit requirements constituting the elements of the path requirements for the three scenarios used as examples are contained in Appendices B through D. The path requirements are displayed and discussed in Chapters 8, 9, and 10.

4-6 EVALUATION OF IMPACTS

Once the requirements are known for a given path of action, the next step is to elucidate and evaluate the technical, environmental, economic, social and political impacts of those requirements.

It is convenient to divide the impacts into primary, secondary and higher. Primary impacts are those which are a direct consequence of the requirement. For example, suppose that a path calls for building 30 coal fired electric generating plants in a given year. The building of these plants will require given amounts of coal, steel, water, cement, manpower, etc. The primary social impact of using a certain number of engineers and other labor to build the power plants is that the manpower is not available during that period to produce something else which may also be socially desirable such as bridges, hospitals or buildings. A primary environmental impact of the plants would be the amount of SO_2 and particulates that each plant would emit.

The secondary and higher impacts on manpower include the effect a sudden increase in the labor force might have on a particular area in terms of a need for new housing, roads, schools and fire and police protection. Each of these new requirements in turn generate additional demands for manpower, materials, equipment and capital. A higher order impact would be the effect on the teacher training system of having to produce more teachers to staff the new schools. A secondary environmental impact would be the change in precipitation patterns in the area of the power plant due to increased levels of water vapor and particulate matter.

The process can be continued further, but the web of impacts becomes so complex and diffuse that, in general, the discussion in this report will be confined to primary and secondary impacts.

Examples of selected impact areas in various categories are as follows:

Technical Impact Areas
- Design facilities
- General production facilities
- Capacity to produce scarce equipment
- Technical manpower utilization

Environmental Impact Areas
- Air quality
- Water quality
- Water use
- Land use
- Sound levels
- Biological activity
- Solid waste production
- Thermal pollution levels
- Radioactivity levels

Economic Impact Areas
- Demand for capital
- Wages
- Inflation
- Price of energy
- GNP

Social/Political Impact
- Housing
- Schools
- Roads
- Fire/Police protection
- Sewers
- Sewage treatment
- Public transportation
- Training
- Government
- Other institutions
- Individual freedom
- Government regulation
- Life-styles
- Standard of living

One way to display the impacts of various requirements or action is shown in Figure 4-5. The scale ranges from Very Good (++), Positive (+), No Effect (0), Negative (-) to Very Bad (--). Numerical scales or words can also be used. The line between these categories is judgmental, but the matrix provides a concise display of the qualitative impact of a given set of actions.

The listing of impacts is much easier than the next step which is the evaluation of these impacts. If possible, it is first of all desirable to know the absolute magnitude of the impact, e.g., 300 tons of SO_2 per day emitted by a power plant. It becomes more difficult to turn the emission rate into a figure for ambient air concentration because of the many additional variables involved such as temperature and wind speed. It is even more difficult to turn the ambient air concentration into an estimate of the health risk to humans or the damage risk to plants. Yet it is the health risk impact which is often the most important to decision makers. Despite such difficulties it is important to make such evaluations as carefully as possible in order to determine the true social cost of a proposed course of action.

In this report, the emphasis is placed on uncovering the impacts and their magnitudes rather than attempting to make value judgments about them. Value judgments of this sort should be left to decision makers and the wider society. Chapters 8, 9, and 10 contain a discussion of some of the costs and benefits of the impacts of each path, but no attempt is made to draw conclusions from cost/benefit ratios.

Impacts / Actions	IMPACT 1	IMPACT 2	IMPACT 3	IMPACT 4	IMPACT 5	IMPACT 6	IMPACT 7	IMPACT 8	IMPACT 9	IMPACT 10
ACTION 1	-	-	+	0	0	-	+	0	-	+
ACTION 2	+	-	0	0	+	-	+	-	+	++
ACTION 3	0	-	+	-	-	0	+	+	-	0
ACTION 4	-	--	+	+	0	+	-	0	0	-
ACTION 5	0	+	-	0	--	+	-	+	+	-
ACTION 6	-	+	0	+	0	-	0	-	0	-
ACTION 7	+	0	0	-	+	-	-	0	+	-
ACTION 8	-	-	+	-	0	0	+	0	-	0
ACTION 9	0	+	-	0	-	0	+	-	-	0

FIGURE 4-5 IMPACT MATRIX. THIS MATRIX GIVES A QUALITATIVE MEASURE OF THE IMPACTS OF VARIOUS ACTIONS. THE RANGE IS VERY GOOD (++), POSITIVE (+), NO EFFECT (0), NEGATIVE (-) AND VERY BAD (--).

4-7 DISPLAY ALTERNATIVES

The display of the results of a systems approach study is an important requirement. Several criteria must be considered in trading off display alternatives. Primarily, though, a display should be easy for the reader to follow. Unfortunately, no one display is the best for all readers.

The choice of a display was not easy for the MEGASTAR group. The purpose of this effort was to display a methodology which, when applied to energy scenarios develops the requirements, impacts and critical issues pertinent to the scenarios. The group applied the methodology to three scenarios.

Two alternative means were examined to display the three examples. The basic differences in these alternatives are indicated by considering the matrix.

Consideration \ Scenario	Path 1	Path 2	Path 3
Requirements			
Manpower			
Materials			
Capital			
Impacts			
Technical			
Environmental			
Economic			
Social/Political			

The matrix suggests two ways for subsequent organization of chapters in this report. One way is to organize the chapters on applications of the methodology as follows:

Chapter X	Requirements	Chapter Y	Impacts
X-1	Path 1 Manpower Materials Capital	Y-1	Path 1 Technical Environmental Economic Social/Political
X-2	Path 2 Manpower Materials Capital	Y-2	Path 2 Technical Environmental Economic Social/Political
X-3	Path 3 Manpower Materials Capital	Y-3	Path 3 Technical Environmental Economic Social/Political

The display alternative emphasizes the methodology rather than giving emphasis to the analysis of the three examples.

The other way to organize the report is according to path. This is the method chosen for this study and Chapters 8, 9, and 10 constitute the display in detail. It is felt that this organization displays the methodology as well as does the method above where requirements and impacts are called out as chapter headings. By following through one one example at a time, it is intended that the reader will better see how the methodology works in practice. The display is not intended to attack or support any of the scenarios examined.

4-8 TRADEOFFS

Once the paths and their associated requirements and impacts have been identified, the final step is to examine them for any possible trade-offs. Tradeoffs represent the process of finding alternate courses of action which lead to the same result, but which better meet the criteria or constraints associated with the objective. If two different actions satisfy the same requirement, but one satisfies a certain constraint while the other does not, the latter would not be preferred. For example, let the requirement be to move coal over a long distance with the constraint being minimum use of water. There are two alternatives which meet the requirement: a unit train or a slurry pipeline. However, the slurry pipeline does not meet the constraint of minimum water use. Thus, the tradeoff is to use the unit train.

This process is also closely related to traditional economic cost/benefit analysis where the cost/benefit ratios of various alternatives can be used as a criterion for determining which alternative is most desirable. One of the problems with traditional cost/benefit analysis has been a tendency to underestimate costs, particularly social costs. If social costs are included, then cost/benefit is a useful tool for analysis of tradeoffs.

Another aspect of the process is risk/benefit analysis. It may be the case that two alternatives have essentially the same cost/benefit ratios, but entail different risks. For example, the cost of shipping radioactive material may be essentially the same by track or by train yet the risks in terms of accidents or hijacking will be different. So the risks associated with alternatives need to be considered in the tradeoff process as well as the effects of more traditional costs.

After completion of the tradeoff process and necessary iterations, the final result is obtained. The result will be a set of alternate futures and for each future a set of alternate paths along with their requirements and impacts which satisfy the given constraints and criteria. The decision then has to be made by society or its representatives as to:

Which future is most desirable;

Which path to that future is most desirable; and

How to implement the choice.

CHAPTER 5. EVALUATION OF PRESENTLY AVAILABLE ENERGY SCENARIOS

The prediction of the details for future energy consumption is a difficult process due to the multitude of the factors influencing this consumption. Indeed, the measurement uncertainties, the random nature and the synergistic interactions of these factors make energy forecasting an inexact science at best. During the past few years numerous forecasts have been undertaken by various organizations. Each of these forecasts has its individual characteristics and its own rationale. Recently such forecasts have become topics for comparison and discussion. A summary of these energy projection comparisons is shown in Table 5-1.

The details of several recent energy consumption forecasts are presented in Tables 5-2 and 5-3. The first column of these tables represents the present energy situation for purposes of comparison. Each of these energy scenarios will be briefly described.

5-1 DOI SCENARIO [Dupree-72]

The Department of Interior scenario was written in 1972 and is a "pre-embargo" document. This scenario represents a far-sighted approach based primarily on historical growth patterns. Its stated purpose is to assess the present energy demand and to forecast the future demand as accurately as possible. It is well written, clearly illustrated and well detailed. Because of its "pre-embargo" posture, the DOI scenario relies heavily on the use of oil and gas to meet our nation's future energy needs. This is perhaps its weakest point. For example, in the year 2000 the DOI scenario predicts that 37 percent or 71 quads of our energy will come from petroleum. Of this, only 29.7 percent will come from domestic supplies. The remainder will be required from supplemental supplies such as imports or increased production from new reserve discoveries. In addition, the DOI scenario predicts that 34 quads or 18 percent of our energy for the year 2000 will come from gas. Of this, 28 percent is expected to come from imports. This scenario does not contain suggestions for the implementation of the proposed energy future.

5-2 FORD SCENARIOS [Ford-74]

The Ford Foundation preliminary report was prepared in early 1974. This report presents three alternative futures based on different assumptions about energy growth patterns. The first future is the "historical growth" scenario which assumes that the use of energy will continue to grow much as it has in the past. The second future is the "technical fix"

TABLE 5-1 ENERGY PROJECTION COMPARISONS

Source	Date Written	Number of Projections Compared
Battelle [Battelle-69]	Dec., 1969	19
Federal Power Commission [FPC-72]	Sept., 1972	11
Intertechnology Corp. NSF-RANN [Intertech-72]	Nov., 1972	56
NASA-ASEE TERRASTAR [Terrastar-73]	Sept., 1973	11
National Academy of Engineering [NAE-74]	May, 1974	19

TABLE 5-2 COMPARISON OF SCENARIOS BY SOURCE MIX

SCENARIO / FUTURE	PRESENT DOI	DOI	FORD T. FIX BASE	FORD T. FIX LOW NUC	FORD T. FIX HI NUC	NEE WESTING HOUSE	JCAE	AEC	NAT. ACAD. ENG'G.	EPA LOW	SHELL	NPC II	CEQ
YEAR	1971	2000	2000	2000	2000	2000	2000	1985	1985	2000	1990	1985	2000
TOTAL QUADS (10^{15} BTU)	69	192	120	120	120	200	174	128	110	158	154	125	121
GROWTH RATE	4%	4%	1.7%	1.7%	1.7%	4%	3.5%	4%	4%	3%	4%	4.2%	1.8-.7%
COAL QUADS	13(18%)	31(16%)	31(26%)	45(38%)	23(19%)	58(29%)	37(21%)	31(24%)	22(20%)	23(14%)	28(18%)	38[c](30%)	33(28%)
OIL QUADS	30[a](44%)	71[a](37%)	31(26%)	32(27%)	25(22%)	27(14%)	34(19%)	60[b](27%)	29[a](26%)	50[a](32%)	23(15%)	48[a](38%)	25[a](21%)
GAS QUADS	23[a](33%)	34[a](18%)	32(27%)	32(27%)	27(22%)	5(3%)	10(6%)		34[a](31%)	35[a](22%)	15(10%)	35[a](28%)	20[a](16%)
NUCLEAR QUADS	.4(.6%)	49(26%)	18(15%)	3(2%)	37(31%)	90(45%)	52(30%)	17(13%)	19(17%)	45(39%)	35(23%)		35(29%)
HYDRO QUADS	3(4%)	6(3%)	—(—)	—(—)	—(—)	—(—)	5(3%)	4(4%)	—(—)	5(3%)	—(—)	3(2%)	4(4%)
OTHER QUADS	—(—)	—(—)	8(6%)	8(6%)	8(6%)	20(10%)	37[a](22%)	16(12%)	7(6%)	—(—)	53[a](34%)	1(1%)	3(2%)

a) INCLUDES IMPORTS

b) COMBINED OIL AND GAS

c) COMBINED COAL AND NUCLEAR

TABLE 5-3 COMPARISON OF SCENARIOS BY SECTOR OF USE AND BY OTHER ASSUMPTIONS

SCENARIO / FUTURE	PRESENT DOI	DOI	FORD T. FIX BASE	FORD T. FIX LOW NUC	FORD T. FIX HI NUC	NEE WESTING HOUSE	JCAE	AEC	NAT. ACAD. ENG'G.	EPA LOW	SHELL	NPC II	CEQ
YEAR	1971	2000	2000	2000	2000	2000	2000	1985	1985	2000	1990	1985	2000
POP. RATE[a]	D–E	1%(D/E)	0.6%(E)	0.6%(E)	0.6%(E)	1.5%(C)	1.3%(D)	1.5%(C)	—	0.6%(E)	1.5%(C)	1.1%	.7%
GNP RATE	4.3%	4.0%	3.5%	3.5%	3.5%	—	—	—	—	3.0%	—	4.2%	4.0%
RES. & COMM. USE	30%	28%	32%	32%	32%	30%	—	—	—	—	30%	31%	32%
TRANSPOR. USE	30%	41%	22%	22%	22%	26%	—	—	—	—	32%	37%	48%
INDUSTRY USE	40%	31%	46%	46%	46%	44%	—	—	—	—	38%	32%	19%
GAME PLAN[b]	—	NO	YES	YES	YES	YES	NO	NO	YES	YES	NO	YES	YES

a) TERMINOLOGY FROM U.S. BUREAU OF CENSUS [US CENSUS -72]

b) "GAME PLAN" MEANS A PROPOSED TECHNIQUE FOR IMPLEMENTATION

scenario which reflects a determined, conscious national effort to reduce energy demand through the application of energy-saving technology. The third future is the "zero energy growth" scenario which represents a break with accustomed ways of doing things. This scenario does not preclude economic growth but it does provide a zero energy growth situation in the year 2000. Each of these scenarios is further generalized by considering alternative mixes of resources to achieve these futures. For example, the "technical fix" scenario is divided into base case, low nuclear case and high nuclear case mixes. This document does provide a game plan for implementation and does assess some of the consequences of these implementation techniques. The final report of the Ford Foundation will be published later in 1974 and should contain a more comprehensive picture of the three alternative scenarios.

5-3 NEE SCENARIO [Ross-73, Creagan-74]

The Nuclear Electric Economy scenario was prepared in 1973 and modified after the oil embargo. It is based on the premise that any realistic approach to solving the energy crisis should be based on reducing U.S. dependence on oil and gas. It, therefore, proposes that a shift be made to a more abundant fuel base. In particular, the Nuclear Electric Economy scenario suggests an economy which is strongly dependent on the electricity generated by nuclear fission. In this scenario the production of electricity by the year 2000 is up 50 percent while the use of oil and gas is down by a factor of three. The use of coal is up over 70 percent and total energy end use consumption is down more than 30 percent. This trend in consumption is suggested to be possible by means of greater end-use efficiencies of electricity. Although not as detailed as some of the other scenarios, the Nuclear Electric Economy scenario does include information on the technological changes necessary for its implementation. These include the use of heat pumps for space heating applications and the use of electric powered vehicles in the transportation sector. Implementation of this scenario requires that the present plans and estimates for adding electrical generation, transmission, and distribution capacity should be revised sharply upward.

5-4 JCAE SCENARIO [JCAE-73]

The JCAE document "Understanding the National Energy Dilemma" was prepared by the Joint Committee on Atomic Energy in September 1973. This document was developed as a graphic presentation to enable a person to acquire, in a short time, a broad understanding of the scale and complexity of the national energy dilemma. The uniqueness of this document is not in the data it presents but rather in the system it uses to display this information. As an "option exercise" this document presents an energy scenario to the year 2000 which is based on a reasonable balance in the degree of determination used in assembling the necessary domestic energy supplies. The scenario writers emphasize that this scenario does not constitute an actual recommendation for the future. Rather, it is included to illustrate the method of presentation and to give an understanding of the complexity of the energy problem. The scenario does not have a "game plan" for implementation nor does it attempt to delineate possible impacts.

5-5 AEC SCENARIO [EPO-74]

The "National Energy Future" report or "Dixy Lee Ray" report was prepared in response to President Nixon's directive in his June 29, 1973, energy message. Its purpose and scope are to recommend a national energy research and development program needed to regain and maintain energy self-sufficiency. The report is based on a series of studies carried out under the guidance of the Energy Policy Office in conjunction with various government departments and agencies having energy responsibilities.

The report recommends five major tasks. These are:

Conserve energy and energy resources.

Increase domestic production of oil and gas.

Substitute coal for oil and gas on a massive scale.

Validate the nuclear option.

Exploit renewable resources.

Although this report contains a scenario for the future, it does not discuss the impacts or the implementation of this energy future other than research and development. The report seeks to make a distinction between energy research and development and energy production. This scenario projects only to the year 1985.

5-6 NATIONAL ACADEMY OF ENGINEERING SCENARIO [NAE-74]

The NAE report "U. S. Energy Prospects: An Engineering Viewpoint," was published in May 1974. Its purpose was to assess the realistic steps that might be taken to increase domestic energy supplies and to decrease consumption during the next ten years. The Task Force, which prepared this document, sought to assess the practical feasibility and the likely output of major production programs in the energy area. Potential programs were reviewed to identify the government and industrial actions necessary to implement them.

It also assesses the physical, technical, cost and time schedule aspects of the problem. Because of this, the NAE document represents the best written scenario from the standpoint of implementation and impact. Unfortunately, because of size and time constraints, this scenario was limited to the near future (1985). This scenario does mention that beyond 1985 looms an ominous spectre of greater demand and an even greater potential for an energy problem.

5-7 EPA SCENARIOS [EPA-73]

The EPA scenarios on alternative futures were written in November 1973. Because of the area of interest of the EPA this document places more emphasis on environmental aspects of the future. Thus, the energy portion of the scenario is only a minor part of the total analysis of this document. This scenario does provide a good explanation of the interactions between population, GNP, pollution and energy consumption. In this document four possible futures are displayed. They are: high population - high economic growth; low population - low economic growth; and the two intermediate alternatives. Only the low population - low growth case has been displayed in the table. This document does provide a game plan for implementing desirable environmental futures. While such a plan is not intended to implement an energy future, it does indirectly provide an influence through environmental and economic interactions.

5-8 SHELL SCENARIO [Shell-73]

The National Energy Outlook produced by The Shell Oil Company was prepared in March 1973. This study of the energy supply and demand picture concludes that only oil can supply the major part of the nation's energy growth needs for the next decade. The Shell scenario proports that policy options do exist that can influence the degree of U.S. foreign dependence on imports and the safeguarding of the economy. Although this scenario does not have a "game plan" for implementation it does discuss the role of energy conservation measures and suggests possible government measures that could be utilized to ease the energy supply situation.

5-9 NPC SCENARIOS [NPC-72]

The NPC Scenario was written in 1972 by the National Petroleum Council. The NPC study attempts to present a comprehensive look at the U. S. energy outlook for the next 10-15 years. The conclusions in this study are based on supply-demand balances derived from four supply cases and an intermediate demand projection. Only one of the cases is presented in Tables 5-2 and 5-3. The NPC study assesses the financial requirements implicit in its domestic supply projections and also assesses the balance of trade implications of import projections. The analysis in this study reveals that a very broad range of outcomes in the energy future is possible. As part of its plan for implementation, the NPC report makes policy recommendations for the time period between now and 1985.

5-10 CEQ SCENARIO [CEQ-74]

The CEQ (Council on Environmental Quality) scenario is a response to the energy crisis of 1973-74, and it is based on the assumption that unrestrained growth of energy consumption is impossible and environmentally undesirable. The CEQ scenario is called the "Half and Half Plan"; it proposes that half of the U. S. energy growth in the future should come through expansion of energy sources and half should come through conservation.

The CEQ scenario is basically a future based on an electric economy. Petroleum is almost solely dedicated to transportation and natural gas is a declining energy source. The CEQ plan also includes some solar and additional geothermal energy by the year 2000.

The CEQ scenario includes a skeletal plan for reaching the year 2000, and the plan also has major implications for the years beyond 2000. The principal element in this CEQ future is a per capita growth rate of .7 percent in net energy use; this is also a goal for the years beyond 2000.

CHAPTER 6. DEFINITION OF TWO ENERGY FUTURES

The Nuclear Electric Economy (NEE) as described by Westinghouse [Ross-73, 73-1, Dunning-74-1] and the Ford Technical Fix Base Case (FTFB) [Ford-74] were chosen as the particular futures to assess. The procedure for choosing a future and defining it is part of the overall methodology presented in Chapter 4. After reviewing the procedure for this subtask each future is defined. General characteristics, source mix, and end use changes are compared with each other and with a baseline projection of what the future would be like were no change to be made.

6-1 CHOOSING THE TWO FUTURES

One of the requirements of the overall objective is to define futures (Figure 4-1). The choice of a future followed the systems design scheme:

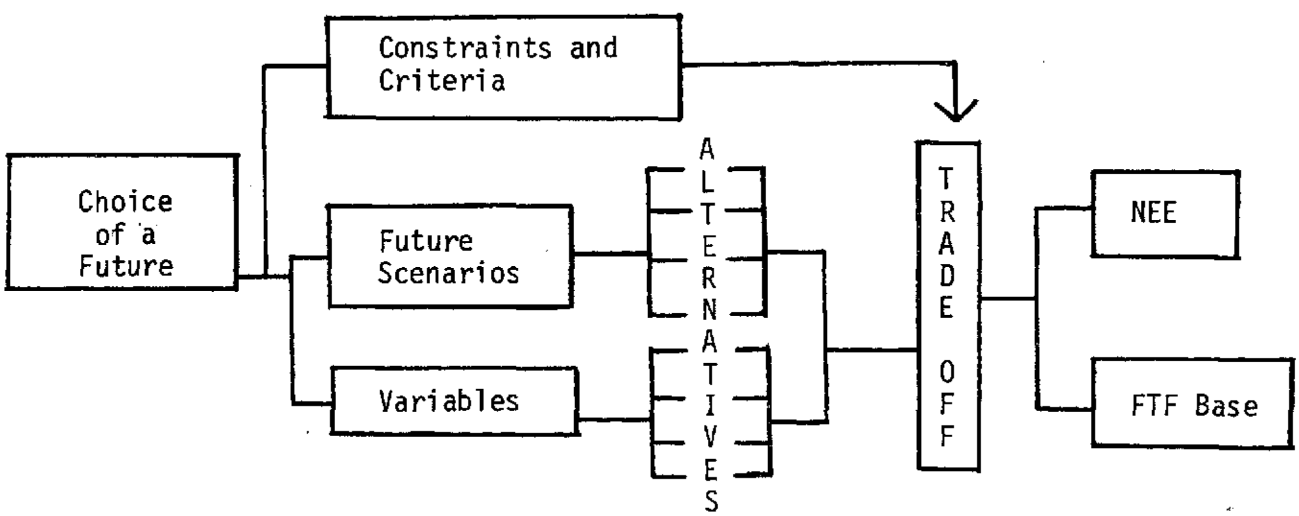


Table 5-2 and 5-3 show the scenarios that were examined in detail and the variables that were considered. Constraints and criteria were discussed in Chapter 4. The dominant ones used in choosing the NEE and the FTFB were

as follows:

Politically and industrially well-known, popular, and judged likely to occur;

Energy and slope predicted at the year 2000 (the next ten years are nearly fixed . . . beyond 2000 would be too speculative);

Source and use mix proposed and documented;

A suggested implementation plan that includes technical fixes (conservation through efficiency using present technology);

Present economic impetus maintained;

Needed industrial skills available:

Near energy independence; and

Limited to the U.S.

These criteria were not judged to lead to the best energy future for the greatest good of all. They were judged to be either necessary to assess a future, or necessary to be credible to most people in decision-making positions. Chapter 5 has discussed some details for each scenario.

6-2 OVERVIEW

The NEE, the FTFB, and a baseline future for the year 2000 (what 2000 would be if we made no change) are displayed and compared with the present [Ford-74] and with the AEC's Dixy Lee Ray 1980 and 1985 projections [EPO-74] in Table 6-1. For 1972 coal (11 Quads), oil (33 Quads) and gas (23 Quads) make up 15 percent, 46 percent and 32 percent of the source mix respectively. This compares with 32 percent, 43 percent and 21 percent for the world's consumption [Felix-72]. Total world consumption is triple that of the United States. Table 6-1 shows that the huge oil and gas and huge coal consumption continues at the year 2000 for the baseline. They are reduced in percentage because nuclear's 54 Quads comprise 27 percent of the total. It is important to recognize that this baseline projection is close to what three different scenarios predict if the U.S. makes no national effort to change anything.

The post-embargo [EPO-74] 1980 and 1985 projections show a lower oil consumption than the baseline because Project Independence arbitrarily set oil imports at zero. If gas consumption does not increase, domestic oil would have to increase in order to equal the total of 56 quads shown in Table 6-1 by 1985 for oil and gas. The total quads in 1985 shown in Table 6-1 are lower in EPO-74 relative to DOI because of the conservation effort that is part of the Dixy Lee Ray scenario.

TABLE 6-1 COMPARISON OF ENERGY QUADS FOR TWO FUTURES PLUS BASELINE

		Baseline[a]						FTFB	
	1972	DOI 1980	DOI 1985	2000	EPO-74 1980	EPO-74 1985	NEE[c] 2000	1985	2000
Total Quads	72	96	117	200	89	105	207	95	120
Energy/yr.	4%			4%			4%		1.7%
Pop./yr.	1.5%			1.5%			1.5%		.6%
Coal, Direct	11	16	21	38	20	29	39	18	25
Coal, Syn. Fuel						gas	14	2	6
						syn. fuel	13		
Oil, Dom.	23	42	51	102	46.5[d]	56	20	25	36
Oil, Imp.	10				12.5	0	2	1	0
Gas, Dom.	21	27	28				9	32	28.5
Gas, Imp.	2						0		4
Nuclear	2	7	12	54	8	16	94	12	18.5
Hydro, etc.	3	4	4	6	3	4	16	5	7
Conservation					(10)[b]	(15)[b]			
Residential	12			18			13		11
Commercial	9			20			15		13
Transportation	18			45			24		24
Industry	20			54			40		38
Processing	13			64			115		34

a) Pre-embargo DOI [Dupree-72] projections were used for 1980 and 1985. For 2000 an average of DOI and post-embargo NEE base [Ross-73] and Ford historical [Ford-74] was used. Post-embargo differs in that oil and gas are down 5%, coal up 4%, and nuclear up 1%.

b) Must be added to total quads if savings not achieved.

c) Energy consumed in generating electricity for 1972 is 18 quads out of 72 total (25%), for the NEE base . . . 96/207 (46%), and for the NEE itself . . . 150/296 (72%).

d) The 46.5, includes gas, dom. and gas, imp., but not oil imp.

6-3 NEE

The NEE has built into it an historical 4 percent energy growth rate that assumes a 1.5 percent population growth rate [U.S. Census-72, Series C] prior to 1985 and a zero population growth rate (Series F) from 1985 to 2000 [Dunning-74-1]. The nuclear electric economy is characterized at the year 2000 by:

A large continuing energy growth rate;

A huge nuclear energy consumption of 94 Quads;

A high coal consumption;

Oil consumption that is less than at present; and

A much lower gas consumption than at present.

If Project Independence stimulates a rise in domestic oil and gas production by 1985 then NEE must predict domestic oil and gas peaking between 1985 and 1990 before dropping to their total 31 Quads by the year 2000.

Notice in Table 6-1 the huge processing loss in the NEE that is inherent in any electric economy. A total of 115 Quads are lost for 92 Quads of end use in the residential, commerical, transportation, and industrial sectors. Part of the NEE scenario is to bring the breeder on-line. The 94 Quads of nuclear include 32 from the LMFBR (liquid metal fast breeder reactor) and 8 from the HTGR (high temperature gas reactor). The NEE is truly an electric economy. Forty of the coal Quads (10 synthetic gas), 2 of the oil, and all of the "others" category, in addition to all of the nuclear are used to generate electricity. Major transformations to electric cars, heat pumps, waste heat use to generate electricity, and substitution of electricity wherever possible, would have to be made in manufacturing and end use. Westinghouse [Trumbower-74, Ross-73-1] projects:

	Space Heating					Electrical Transportation			
	Residential			Commercial					
	Heat Pumps	Elect. Resis.	Solar	Heat Pumps	Elect. Resis.	Cars	Busses	Trucks	Rail
	10^6 Homes			% of Sector					
1985	6	20		15	48	5×10^6	50% Urban	70% of Local	30%
2000	30	45	10	30	35	100×10^6	100% School		100%

Savings from technical fixes are shown in Table 6-2.

The "others" category is unspecified. Hydro cannot provide more than 6 Quads. It is tempting to assign the remainder to solar plus geothermal. If NASA's program [NSF/NASA-72] were followed, solar would have this capability. Dunning-74-1 favors additional nuclear use.

TABLE 6-2 A COMPARISON OF NEE AND FTF FIXES

Savings, in Quads for the year 2000

End Use Sector / Technical Fix	Heat Pumps, Process Heat, Process Steam	Better Constr.	Furnace/AC. eff.	Solar Htg. & Cool.	Total Energy Systems (MIUS)	Elec. Cars	Smaller Cars	Aircraft, Etc.	Transfer To Rail	Decrease Energy Intensiveness	Metal Recycling	Other	Total
FTF Comm. and Resid.	5.4	4.2	1.5	1.5	.8[a]							3.6	17
FTF Trans.[b]							9.3	2.8	4.1			1.8	18
FTF Industry	13.5									3.8	1.9	5.8	25
FTF, Not Above													5
TOTAL	18.9											11.2	65[c]
NEE Comm.	4						1[d]		1[d]				6
NEE Resid.	4											1	4
NEE Trans.						8			15				23
NEE Industry	2											5	7
TOTAL	10								16			6	40

a) At 30-35% accounts for 2.7 quads or 10-12 x 10^6 people.

b) No electric cars; no mass transit.

c) By 1985, 19 quads.

d) Road oil and asphalt.

6-4 FTFB

Ford's historical growth postulates 185 Quads instead of the 207 Quads projected by NEE. This is a consequence of a 3.4 percent energy growth rate instead of 4 percent (average since 1950 rather than since 1965). TERRASTAR-73 points out that the 4 percent growth rate reflects the Vietnam War situation. It is hard to know what an optimum peace-time energy growth rate might be. The FTFB suggests the same end use of energy as does historical growth, but asserts that 185 Quads can be cut to 120 Quads by technical fixes, i.e., improvements in end use efficiency of energy (See Appendix E-2). These are listed and compared with those from NEE in Table 6-2.

In addition, FTFB is characterized by huge oil and gas consumption, nuclear close to AEC's [EPO-74] for 1985, and coal at a level comparable to the baseline. Oil and gas resources are traded off for minimal risk to the environment from coal and nuclear reactors and their waste. The FTFB would require new technology to come on line by 2000 to maintain the conservation ethic or the energy growth rate would climb again. FTFB does not change the consumer's end use of energy, only the efficiency with which energy is consumed. No curbing of the "growth is good" ethic is hinted at. After the year 2000 energy growth would parallel historical growth once again. If this were taken literally, lead times would require planning in the 1990-2000 decade. Such planning was not taken into account in this report.

CHAPTER 7. ALTERNATIVE PATHS

This chapter describes the decision process that was used to select alternative paths to specific futures and the alternates selected. In this method of energy assessment, the scenario is assumed to be divorceable from the given scene at a future point. The method then defines alternate paths to the future point. The specific future points are described in Chapter Six. The elements of an alternate path definition are contained in Chapter Four.

7-1 INTRODUCTION - OVERVIEW

As originally formulated, the two futures, NEE and FTFB, were to each have alternate paths defined and assessed. The NEE future was taken as one embodiment of an historical energy growth forecast. The FTFB future was taken as an embodiment of an intermediate growth forecast. These two scenarios were especially attractive for analysis because of the detail available about implementation. Upon closer examination of the scenarios [Ross-73] and [Ford-74], it became clear that the two futures are remarkably similar in features other than energy. Ford [Ford-74] states explicitly that the technical fix scenario (FTFB) has a historical growth economy in terms of quality of home life, travel and mobility, and size and distribution of GNP. Thus, within the meaning herein of alternative paths, the Ford Technical Fix is an alternate to the specific historical growth scenario, the Nuclear Electric Economy. The two scenarios as given by their authors display alternate energy use levels, alternate growth rates, and alternate fuel mix. These three factors are the basic constituents needed for the definition of an energy future. The two futures are alike in economic, social, and political dimensions. The FTFB is historical in most things except the historical connection between economic growth and energy consumption.

The definition process of an alternate path was applied to the Ford Technical Fix-Base Case. The specific feature of the original FTFB scenario which was altered was the rate of energy growth at the year 2000. The feature of growth which is generally avoided in other scenarios is the point of change of slope on the "S-curve" of consumption of a finite resource. Considerations of limits to growth lead naturally to scenarios of slow or zero energy growth. Thus, the alternative proposed for the FTFB case was one in which the growth of energy use reaches zero in the year 2000.

The three paths, while defined for two different energy consumption levels in the year 2000, are a set of linked alternates. The

FTFB achieves the economic and social conditions of the historical growth without as much energy consumption. The alternate defined herein achieves the same social and economic goals with a reduction in the growth rate at the year 2000.

A possible alternative path means bending the fuel mix and total consumption curves to achieve a graphical goal without doing violence to the assumptions of minimum dislocations in the economy. Zero growth has been considered since it contains very powerful consequences if it is to be maintained as a national policy for very long. For this study, the year 2000 is another of the reassessment points in the energy development rather than the gateway to a permanent future. One of the elements of an alternate path is precisely the set of tests and the set of achievements and failures available for assessment at that future point. Zero energy growth will not be understood and its consequences not well defined until we have experienced some of the transition to that condition. To repeat, a major element of this alternate path is the introduction of definite reassessment points and the policy formation structure assumed to be controlling the path. This must be clearly distinguished from scenarios in which blind exponential growth is supposed to occur because historically it already has.

7-2 ALTERNATE TO FORD TECHNICAL FIX PATH (AFTF)

This path, which was defined by the study group, is a lowered growth rate, lowered energy consumption alternative to historical growth. It is not a precise alternate to the NEE path because no attempt was made to correlate the differences in fuel mixes to the differences in implementation methods. This path shares all the major assumptions of the Ford Technical Fix Base Case with one major exception. This exception is that the AFTF path reaches zero energy growth so that the question of growth after 2000 is an option. In the statement of the Ford scenario [Ford-74], growth after the year 2000 may return to historical rates since provisions for permanent reduction in growth rate are not included in the scenario.

The interesting feature of this path is that it has a "turnover", i.e., a change from a period of initially high growth to one of zero energy growth. It was felt that this turn down raised many interesting problems of social adjustment and, therefore, this path represents an alternative to the Ford path.

This path has already been partially described as an example to illustrate some of the elements of an alternate path. Specifically, it ends with ZEG and assumes the existence of an ongoing assessing, policy making and implementation activity. The years 1972 and 2000 constrain the fuel mix at the ends. Other specific constraints utilized were:

> Vanishing of the oil imports in the late 1980's, but not natural gas imports;

Updated projections on nuclear capacity for 1980 [NUC NEWS-74];

Appreciable growth in the category of other fuels recognizing the limitations on the expansion of conventional sources such as hydroelectricity; and

The absence of strong population pressure.

Gross constraints on the consumption curve besides smoothness were:

Close approach to ZEG well before the target date; and

Close approach to current growth rate in the present.

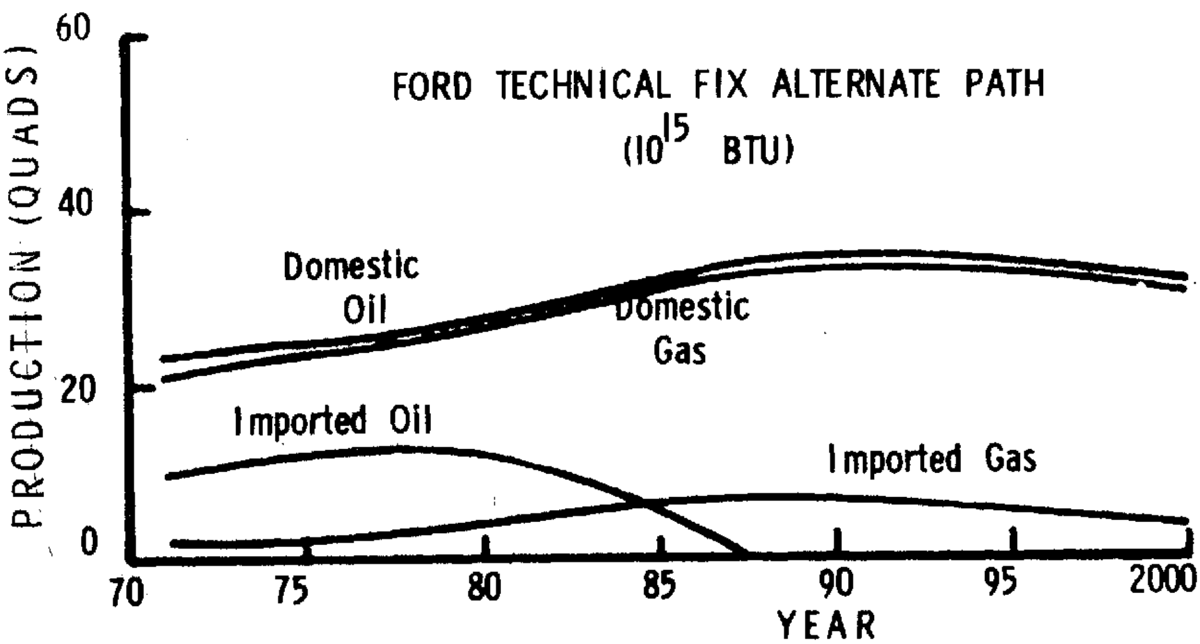
The curves as displayed for the fuel mix have been adjusted twice to achieve the general features desired. It is recognized that this graphical construction is done without economic or social model support. The hope is, of course, that this path is somehow representative of the type of transition behavior from growth to no growth.

Figure 7-1 and Table 7-1 display the evolution of the fuel mix under the AFTF scenario. Figure 7-4 displays the gross consumption patterns of the three scenarios. The adjustment period is not explicitly shown and a smooth interface to the present is included. This ignores the very interesting adjustments of the fall and winter of 1973 which have not been fully assessed particularly as to duration of their impacts without additional reinforcement. The near term third of the alternate path and the fuel mix elements show a compound growth. This curve shows the period 1985-86 as the beginning of the turnover period to lower growth. Thus, the decade 1975-1985 is the time for planning and base building of the change factors with 1984 as the assessment point. This deduction greatly alters the view of priorities for the decade 1975-1985 and shows that policy must begin now and be applied consistently over the immediate future. Since the ZEG goal was set ahead of the year 2000, the transition period lasts only 5 to 7 years. This leaves the period of the late nineties for an operational evaluation of the ZEG concept. It has been pointed out that in many instances government policy has not been pursued sufficiently long or consistently for the impacts to be established and for the desired corrective measures to take effect. One of the steps in impact analysis will be the determination of the requirements for guaranteeing consistent application of long-term policy. It is apparent from the figure that the consumption during the period 1980 to 1995 is significantly higher than the technical fix case. There are several suggestions for viewing this difference which will be considered in the assessment:

This surplus may not be consumption but excess supply;

This surplus could be committed to those changes needed to prevent the Ford Technical Fix from regaining the historical growth rate when its conservation methods saturate;

The surplus may be necessary to cover deficiencies in the achievement of all of the conservation goals;



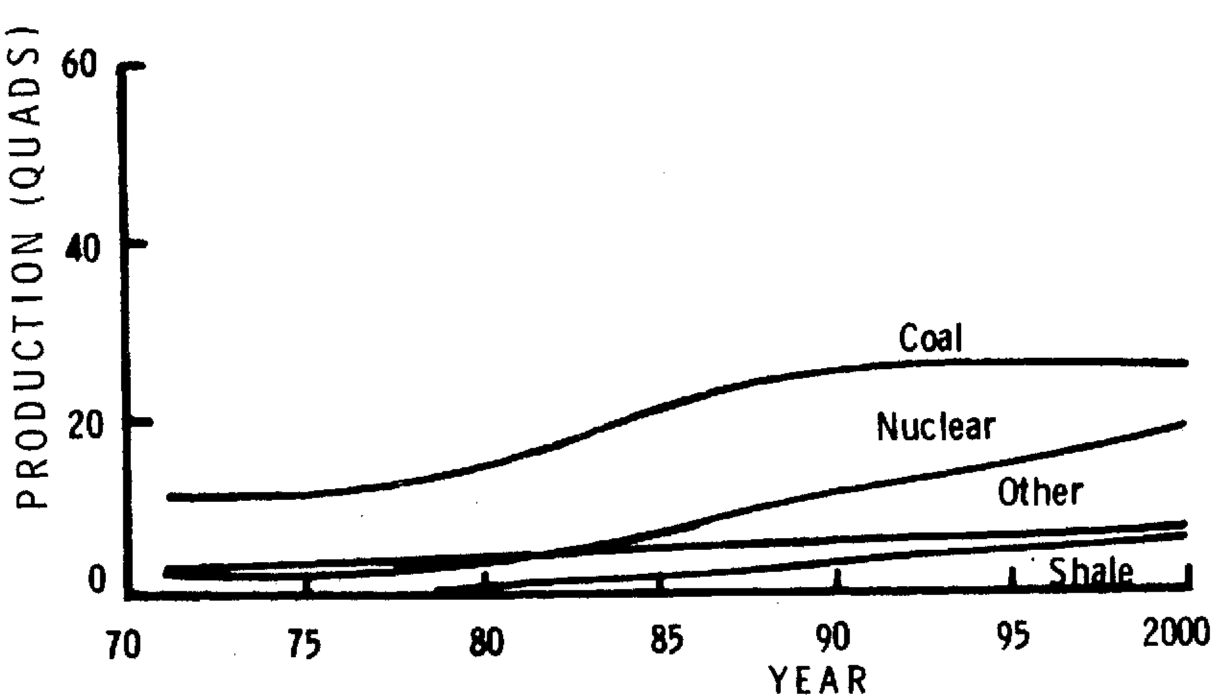


FIGURE 7-1 FORD TECHNICAL FIX ALTERNATE PATH - PRIMARY FUEL PRODUCTION [Ford-74]

TABLE 7-1 ALTERNATE PATH TO THE FORD TECHNICAL FIX
BASE CASE, GOAL IS ZERO ENERGY GROWTH IN 2000 A.D.[a]
PRIMARY FUELS
QUADRILLION BTU

	72	75[c]	80	85	90	95	2000[b]
Coal Direct	11	Adjustment	17.2	21.2	24	24.8	24.8
Coal Total[d]	11	Adjustment	17.2	21.2	24	24.8	24.8
Oil Dom.	23	Adjustment	27.3	31.4	33.8	32.8	31.2
Imp.	10	Adjustment	11.4	5.1	0	0	0
Shale	0	Adjustment	1.0	2.1	3.4	4.7	6
Coal	0	Adjustment	0	0	0	0	0
Gas Dom.	21	Adjustment	26.1	30	32.6	31.6	29.7
Imp.	2	Adjustment	3.6	6.1	6	4.8	2.7
Coal	0	Adjustment	0	0	0	0	0
Nuclear[e]	2	Adjustment	3.3[f]	7	10.7	14.4	18.4
Other[g]	3	Adjustment	4.2	5.1	5.6	6.4	7.2
TOTAL	72		94.1	108	116.1	119.5	120

a) This alternate path was generated to fulfill an objective of lowered growth rates.
b) [Ford-74]
c) The fuel mix in 1975 is not specified since the period 75-80 will be one of considerable adjustment of price changes.
d) The total coal figure includes synthetic fuels.
e) Gross thermal BTU's. To convert to net electrical output assume an efficiency of about 32 percent.
f) This is based on the current AEC projections of about 100 GW installed.
g) Hydropower is presently about 3 Quads with an upper limit of 6 Quads.

The surplus may be necessary to correct inequities in the distribution of per capita consumption; and

The surplus may be necessary to bolster other major areas of concern particularly agriculture, water, environment, and pollution.

Figure 7-1 displays one fuel mix scenario which fulfills the constraints stated at the beginning. It is by no means unique but it is not highly flexible. As long as one avoids sudden interruptions in supply or catastrophic changes in acceptance of the mix the curves cannot be varied much. The nuclear component arrives at 2000 with the largest and longest growth record. This is aggravated by the low value of nuclear capacity projected for 1980. Both oil and gas arrive at 2000 on a downward slope. Such behavior can be connected to possible conditions on discovery and production which will be examined in the assessment. Further comment on this path will be reserved to the analysis of impacts.

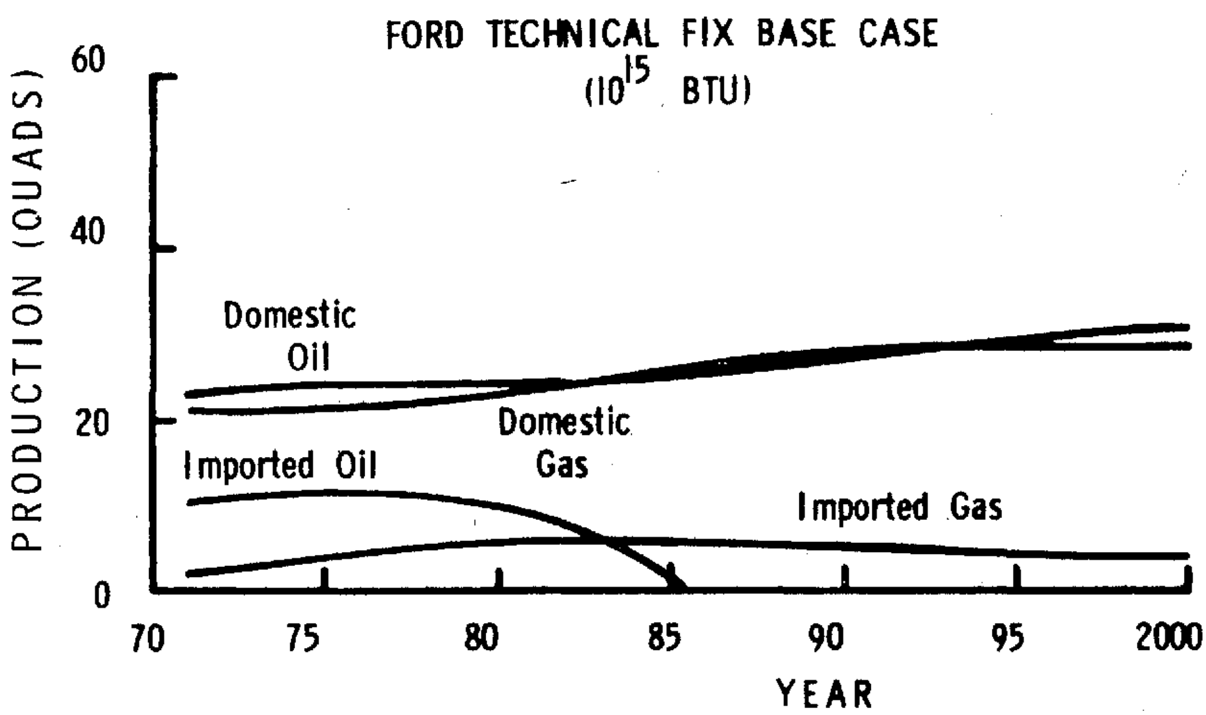
7-3 FORD TECHNICAL FIX-BASE CASE [Ford-74]

This path can be considered a lower growth alternative to historical growth. The decreased consumption is achieved by utilizing energy more efficiently rather than by cessation of economic or industrial activity or alteration of lifestyle. The term reserved for this type of conservation is technical conservation. This mode of conservation is sometimes referred to as "painless" conservation since it involves doing things to conserve rather than giving up things. The assessment through impact analysis will address the question of whether this conservation is really "painless".

The FTFB scenario is balanced in its fuel mix. No one fuel is predominant. The fuel mix at 2000 is the same as specified by Ford [Ford-74] and as adopted for the AFTF scenario. Figure 7-2 and Table 7-2 contain the details of the fuel mix evolution for this scenario. Figure 7-4 displays the FTFB against the other two scenarios.

7-4 THE NUCLEAR ELECTRIC ECONOMY (NEE)

It was pointed out in the introduction that this scenario is one embodiment of a historical growth scenario. Some of the features of the nuclear electric economy have already been described in Chapter 6. The details of the fuel mix are contained in Figure 7-3 and Table 7-3. This scenario shows reliance on coal (direct and converted) and conventional nuclear for the bulk of the energy production in the year 2000. Figure 7-4 displays the NEE against the other two scenarios.



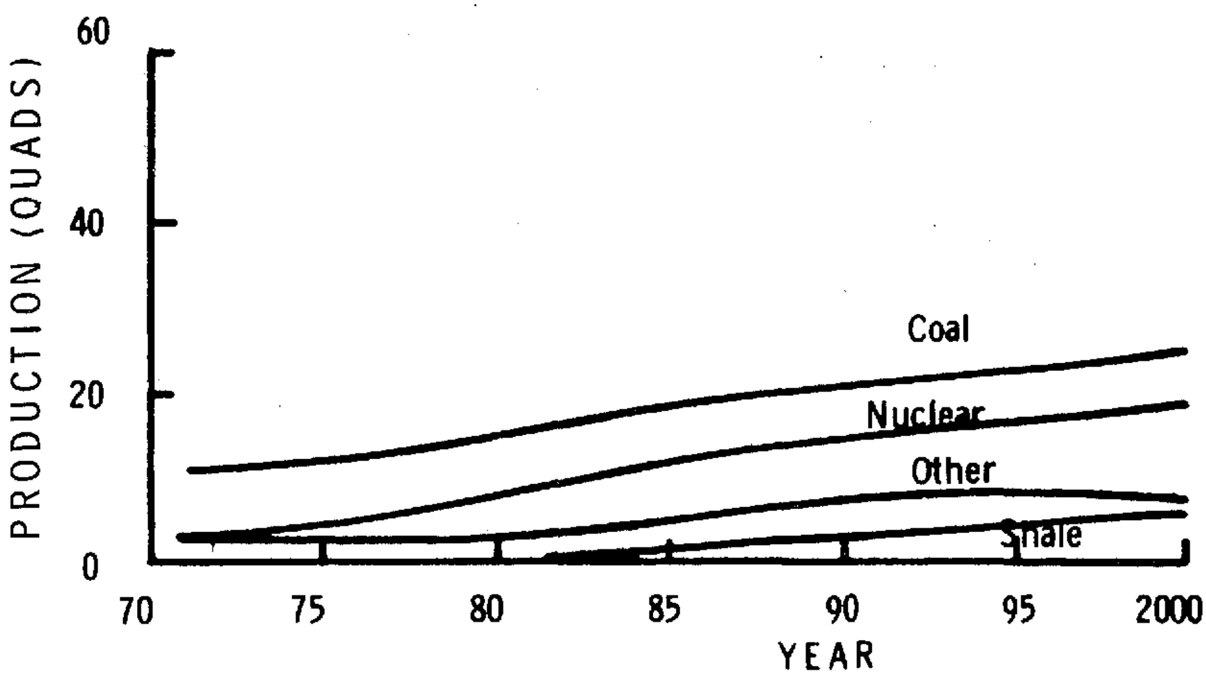


FIGURE 7-2 FORD TECHNICAL FIX BASE CASE - PRIMARY FUEL PRODUCTION

TABLE 7-2 FORD TECHNICAL FIX BASE CASE[a]
PRIMARY FUELS
QUADRILLION BTU

	72[a]	75[b]	80[c]	85[a]	90[c]	95[c]	2000[a]
Coal Direct	11	Adjustment	15.2	18.4	20.0	22.3	24.8
Total[d]	11	Adjustment	15.2	18.4	20.0	22.3	24.8
Oil Dom.	23	Adjustment	24	25.2	27.0	29.0	31.2
Imp.	10	Adjustment	10	1.2	0	0	0
Shale	0	Adjustment	1.2	2.0	2.7	4.0	6
Coal	0	Adjustment	0	0	0	0	0
Gas Dom.	21	Adjustment	23.2	26.6	27.5	28.5	28.5
Imp.	2	Adjustment	5.4	5.5	5.6	5.1	3.9
Coal	0	Adjustment	0		0	0	0
Nuclear[e]	2	Adjustment	7.6[f]	11.6	14.0	16.3	18.4
Other[g]	3	Adjustment	3.4	4.5	6.2	6.8	7.2
TOTAL	72		90	95	103	112	120

a) [Ford-74]
b) The fuel mix in 1975 is not specified since the period 75-80 will be one of considerable ad-adjustment of price changes.
c) Interpolated
d) The total coal includes synthetic fuels.
e) Gross thermal BTU's. To convert to net electrical output assume an efficiency of about 32 percent
f) This value is far in excess of present AEC estimates.
g) Hydropower is presently about 3 Quads with an upper limit of 6 Quads.

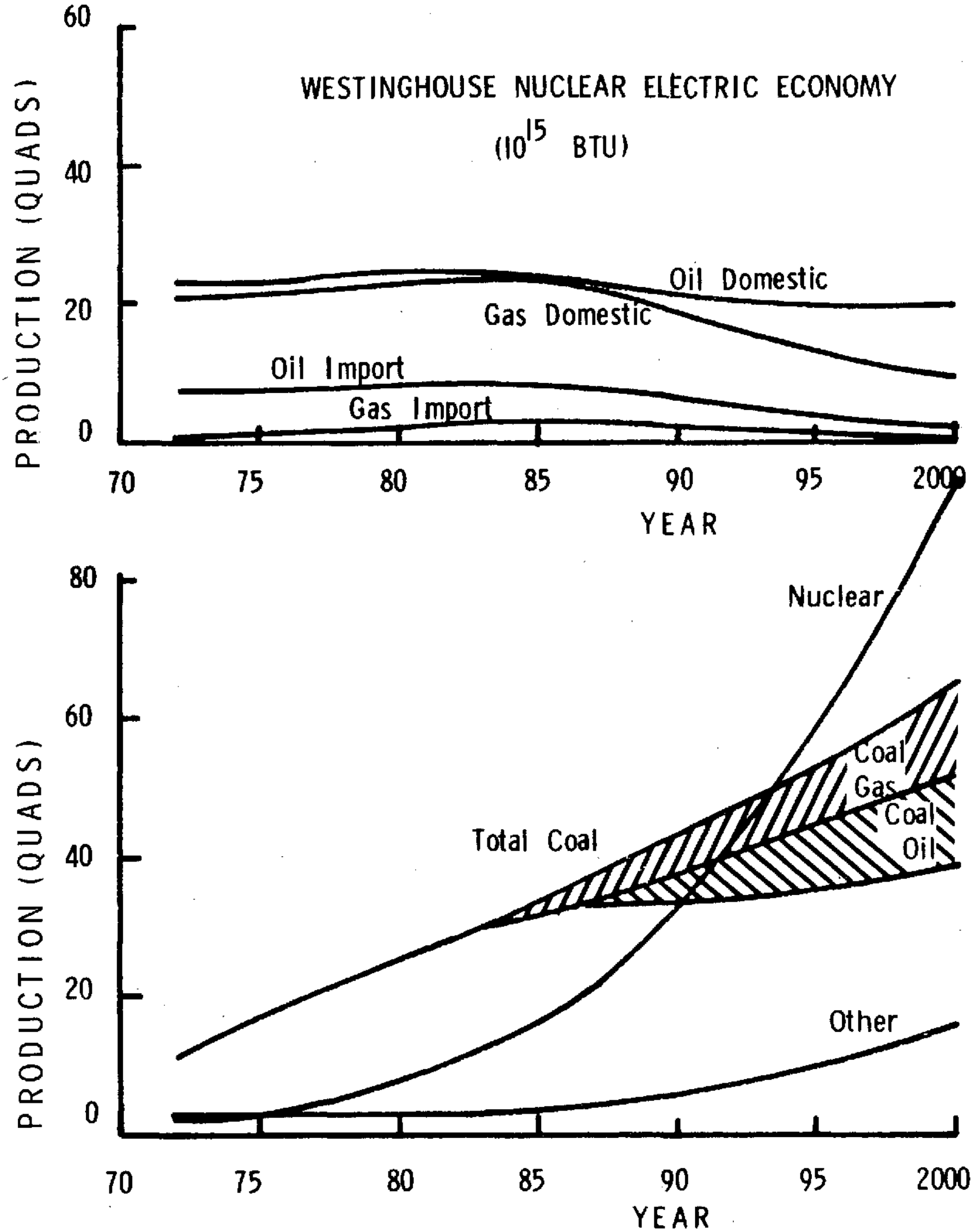


FIGURE 7-3 WESTINGHOUSE NUCLEAR ELECTRIC ECONOMY - PRIMARY FUEL PRODUCTION [Ross-73]

TABLE 7-3 WESTINGHOUSE NUCLEAR ELECTRIC ECONOMY[a]
PRIMARY FUELS
QUADRILLION BTU

	72[b]	75	80[c]	85	90[c]	95[c]	2000[a]
Coal Direct	11	17	25	32	34	36	39
Total[d]	11	17	25	34	44	54	66
Oil Dom.	23	23	23	24	22	20	20
Imp.	10	11	12	6	4	3	2
Shale	0	0	0	0	0	0	0
Coal[e]	0	0	0	0	4	8	13
Gas Dom.	21	22	22	23	18	13	9
Imp.	2	2	2	3	2	1	0
Coal[e]	0	0	0	2	6	10	14
Nuclear[f]	2	2	8	16	33	59	94
Other[g]	3	3	3	4	6	10	16
TOTAL	72	78	95	110	129	160	207

a) [Ross-73]
b) [Ford-74]
c) Interpolated from the data of [Ross-73].
d) Total coal includes the gross coal input to synthetic fuel plants.
e) Synthetic fuel conversion efficiency is taken as 70 percent.
f) Gross thermal BTU's. To convert to net electrical output assume an efficiency of about 32 percent.
g) Hydropower is presently about 3 Quads with an upper limit of 6 Quads.

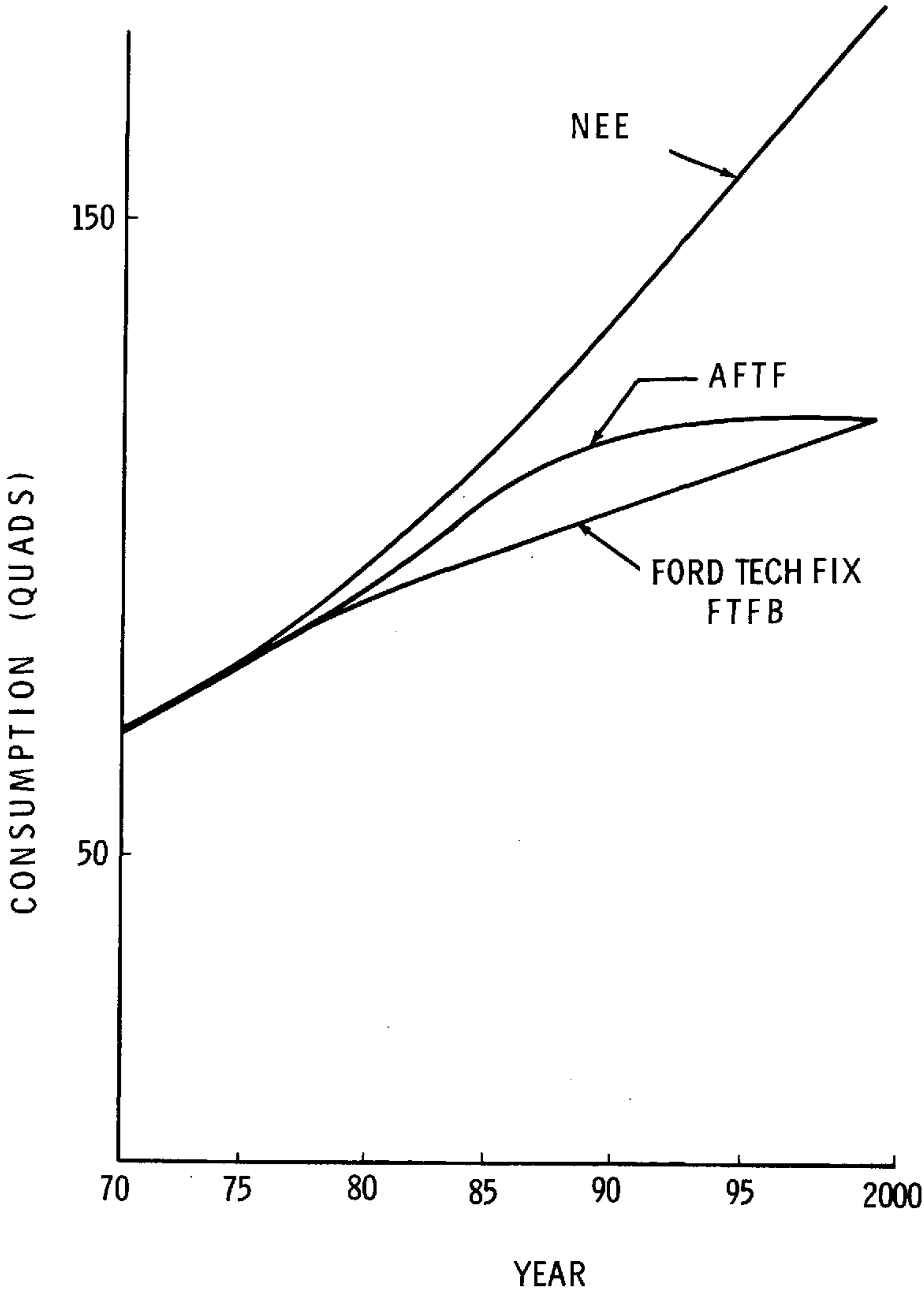


FIGURE 7-4 TOTAL ENERGY CONSUMPTION FOR THE THREE SCENARIOS. NEE [Ross-73]. FTFB [Ford-74]. AFTF IS THE WORK OF THIS GROUP. THIS IS GROSS ENERGY CONSUMPTION INCLUDING CONVERSION LOSSES.

CHAPTER 8. SUMMARY OF THE FORD TECHNICAL FIX (FTFB)

This chapter will summarize the material pertinent to FTFB elaborated in Appendices B, C, D and E of this report as well as some material that is not covered in any Appendix since it does not specifically fall into the categories of the Appendices. Because many of the requirements and impacts of FTFB are similar to those of AFTF, the format of this chapter and Chapter 9 are similar. Chapter 10 differs from Chapters 8 and 9 since the requirements and impacts are substantially different for the NEE path. The difference in format and lay-out also reflect the different views, attitudes and display techniques of the three task groups that wrote the three chapters.

Section 8-1 describes the manpower, material and capital requirements determined as necessary to effect the FTFB. Section 8-2 discusses the impacts that manpower, material and capital requirements will create in the technical, environmental, economic and social/political realms. Those impacts adjudged particularly singular to the FTFB and also those that are common to all three scenarios are presented.

Section 8-3 describes what schedules must be adhered to in order to effect FTFB, when decisions must be made and what trade-offs are possible. Section 8-4 will contain conclusions of the task group about FTFB.

8-1 REQUIREMENTS

In the study of the three scenarios, the interim task groups divided the energy system into the areas of Resources, Generation and Conversion, Distribution and End Use and investigated the manpower, material and capital needs of each area.

It became apparent that Resources, Generation and Conversion, and Distribution were related to the supply of energy. On the other hand, end use was related to the demand side of energy and became difficult to quantify because of the extremely large number of uses and the extreme end use dependence on the supply energy mix. Requirements are thus limited to the supply of energy for the FTFB.

8-1-1 MANPOWER

Manpower requirements were investigated in terms of engineering and non-engineering employees. In the engineering category, disciplines for

the engineers are not delineated. The non-engineering manpower sweeps the employment spectrum from the skilled and craft employees to the unskilled laborer. Overall non-engineering requirements are described and are not broken down further.

Figure 8-1 shows the engineering manpower requirements to the year 2000 for the FTFB. Corresponding data are tabulated in Table 8-1. With the increased level of energy supply with time, the total engineering requirement increases. It levels out at 1995 at 140,000 persons. The leveling comes from the near cancellation of new engineers required in the resource supply area by the decline in need for engineers in the generation and conversion area.

The distribution area requirement for engineers holds almost constant about 33,000. A decline in the need for oil and gas engineers is balanced by an increased requirement for electric power transmission and distribution engineers. No anomolous conditions concerning engineering needs are foreseen.

Figure 8-2 shows non-engineering requirements requirements to the year 2000. The shapes of these manpower profiles largely duplicate those of Figure 8-1. Distribution shows a kink in need from 1985-1990 because of a drip in demand for oil and gas distribution employees which overrides the increase in demand for electric power transmission and distribution non-engineering employees. Again no anomolous conditions are foreseen for non-engineering needs. Whether the correct mix and supply of skilled non-engineering labor will be available when needed is of concern.

8-1-2 MATERIAL

The most common material requirements for the three areas are steel and cement. Steel requirements are displayed to year 2000 in Figure 8-3. No finer resolution was attempted than to describe steel as steel. Classes of steel such as structural, galvanized, and electrical were not defined or quantified and the steel in boilers, turbines, etc. was not included in the generation and conversion area.

Steel requirements in the distribution area fall radically around 1990, reflecting a drop in oil and gas pipelines and tankers construction as FTFB switches away from petroleum. The projected need for steel is one that does not dominate the anticipated steel industry production.

Table 8-2 describes the five year interval requirements for steel and cement. No problems are foreseen in meeting total demand.

8-1-3 CAPITAL

Figure 8-4 shows capital needs to year 2000 for the three areas and the total. Table 8-3 gives the five year interval needs for the various categories. Probably the most significant feature of either display is the growth of demand

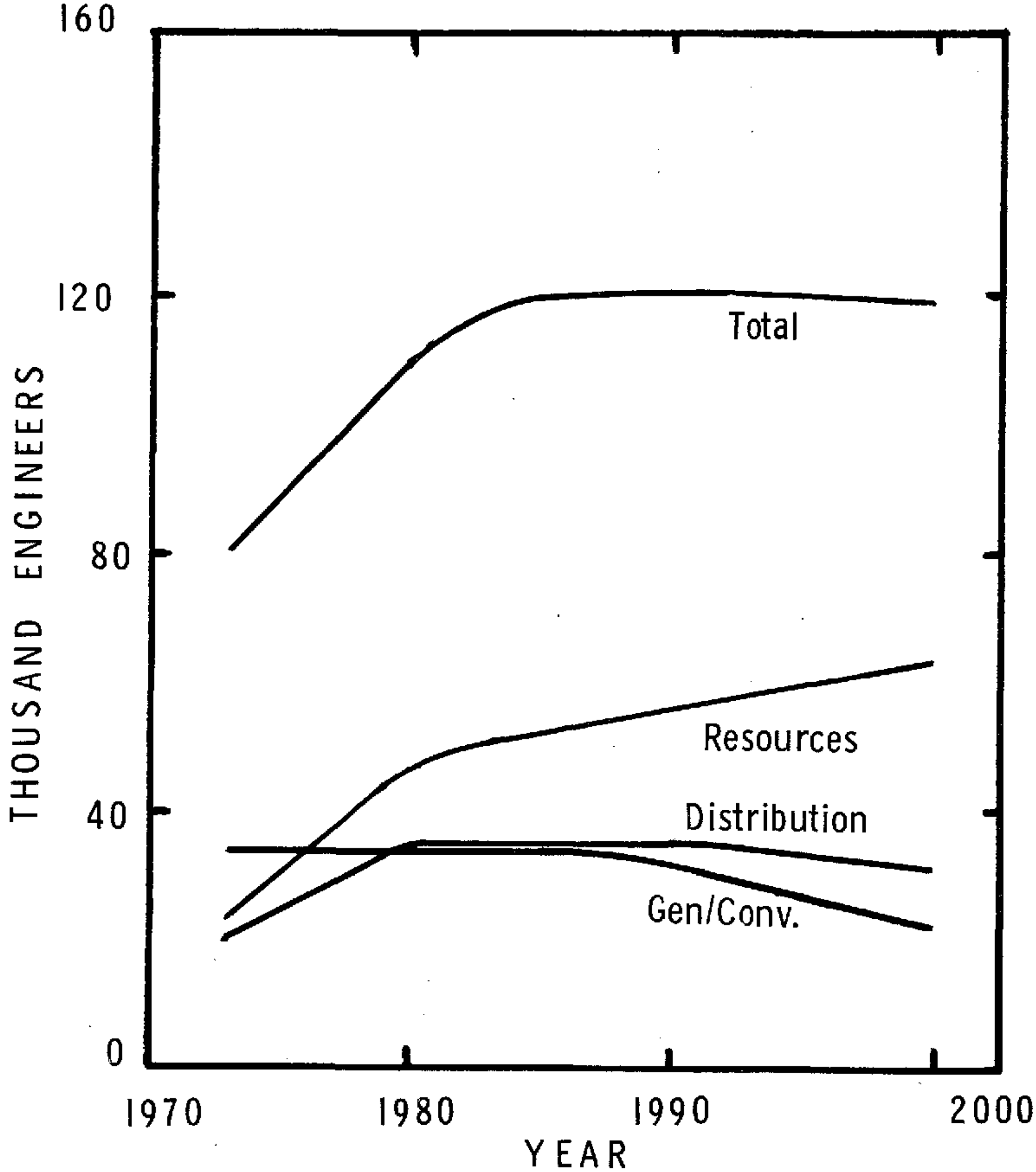


FIGURE 8-1 ENGINEERING MANPOWER REQUIREMENTS FOR FTFB AS FUNCTION OF TIME

TABLE 8-1 MANPOWER REQUIREMENTS FOR FTFB
(THOUSANDS OF EMPLOYEES)

Period Ending	(Present) 1973		1980		1985		1990		1995		2000	
	Engr	Non-Engrg	Engrg	Non Engrg	Engrg	Non-Engrg	Engrg	Non Engrg	Engrg	Non-Engrg	Engrg	Non-Engrg
Resources	26	430	47	560	52	640	56	730	59	820	68	930
Gen/Conversion	34	180	34	190	33	210	31	230	27	230	23	220
Distribution	22	590	32	720	34	820	34	710	33	720	33	740
Total	82	1200	113	1500	119	1700	121	1700	119	1800	119	1900

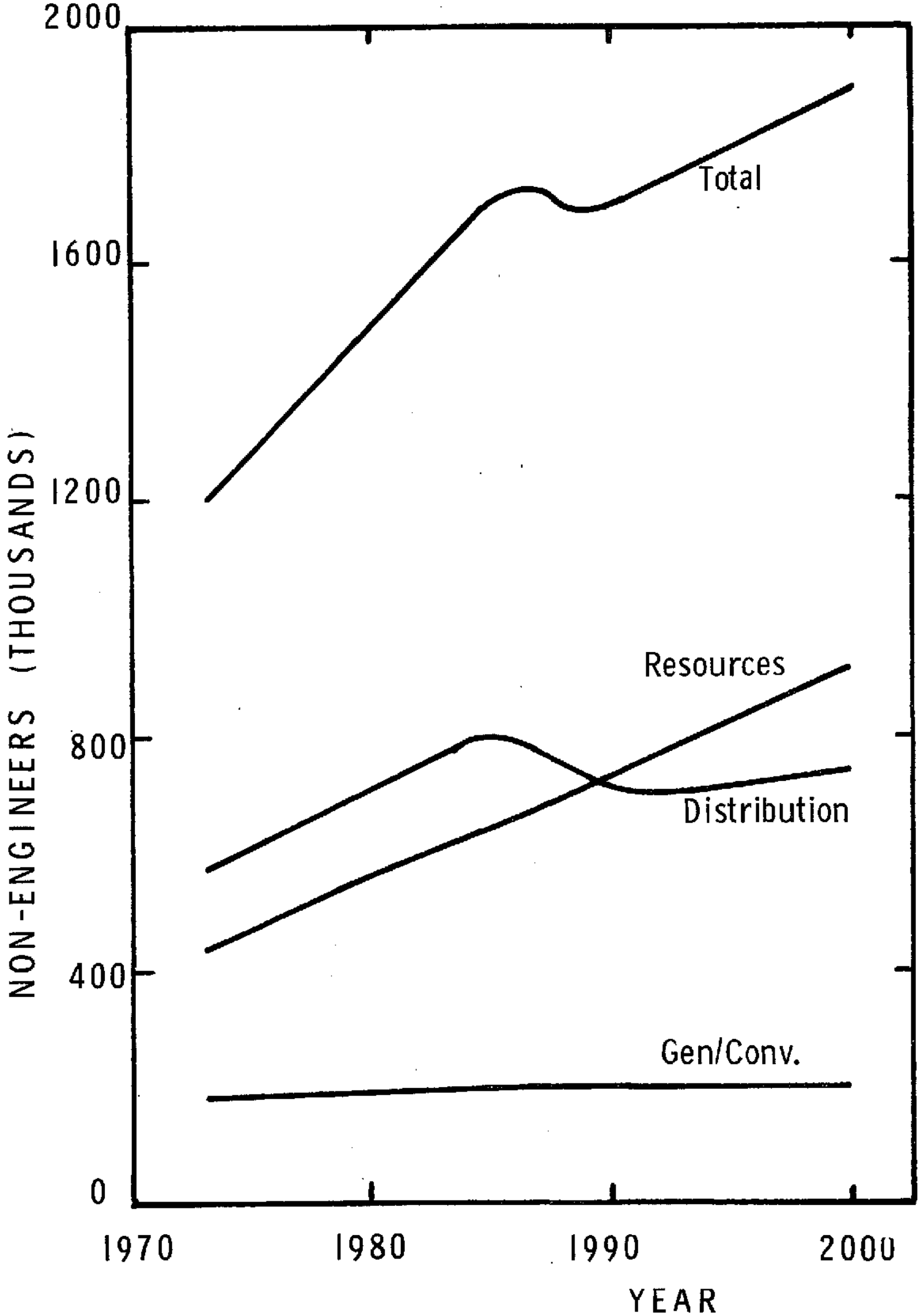


FIGURE 8-2 NON-ENGINEERING MANPOWER REQUIREMENTS FOR FTFB AS FUNCTION OF TIME

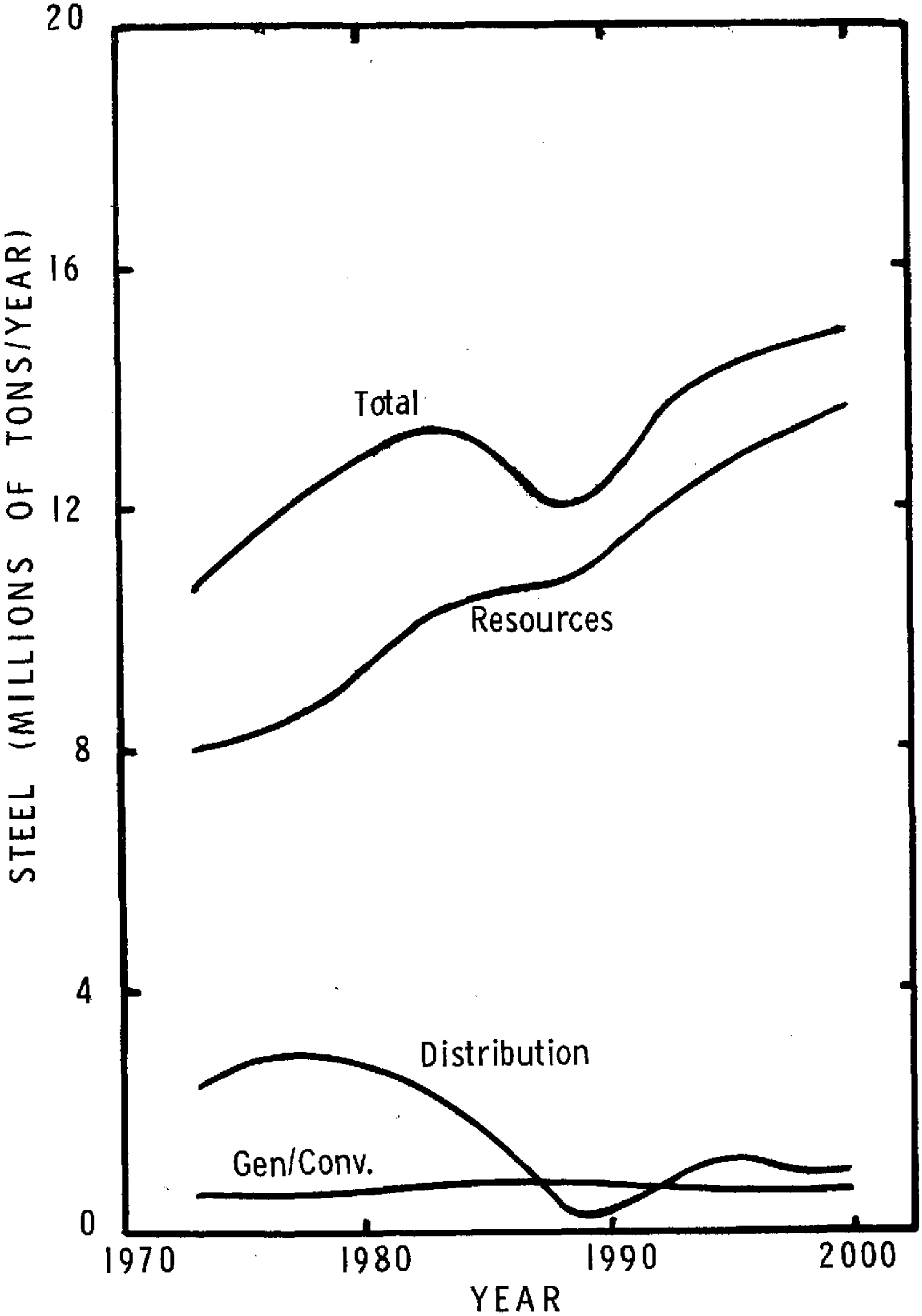


FIGURE 8-3 STEEL REQUIREMENTS FOR FTFB AS FUNCTION OF TIME

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TABLE 8-2 MATERIAL REQUIREMENTS FOR FTFB
(STEEL - MILLIONS OF TONS)
(CEMENT - MILLIONS OF TONS)

Time Period	Present 1973		1976-1980		1981-1985		1986-1990		1991-1995		1996-2000	
	Steel	Cement	Steel	Cement	Steel	Cement	Steel	Cement	Steel	Cement	Steel	Cement
Resources	8	2.5	43	12	52	14	54	15	62	17	67	19
Gen/Conversion	.3	1.0	2.9	2.5	3.5	2.6	3.8	2.3	3.3	1.9	2.6	1.4
Distribution	2.4	-	15	-	11	-	2.4	-	4.4	-	3.7	-
Total			61	15	67	17	60	17	70	19	73	20

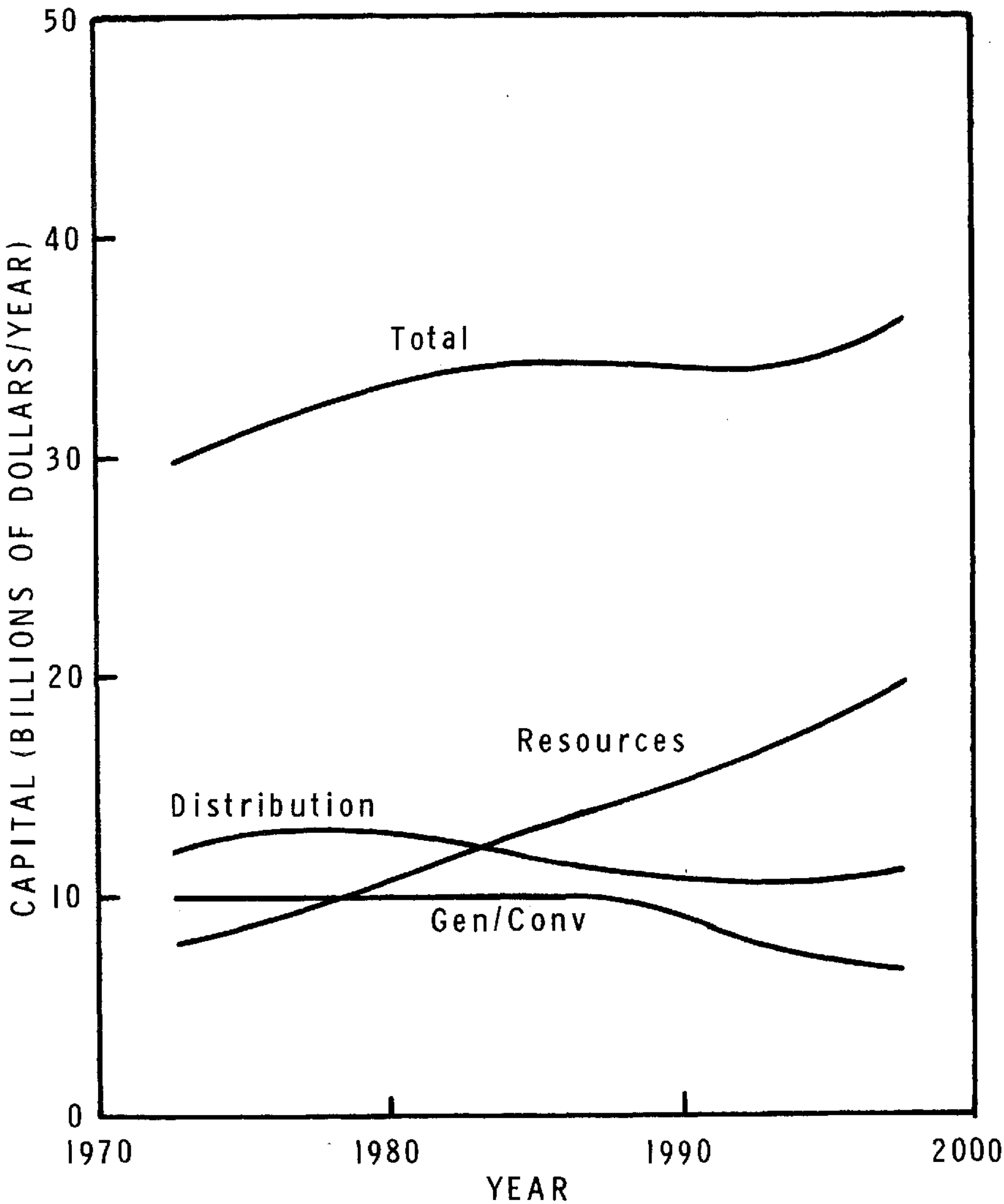

FIGURE 8-4 CAPITAL REQUIREMENTS FOR FTFB AS FUNCTION OF TIME

TABLE 8-3 CONSTITUENT CAPITAL REQUIREMENTS FOR FTFB
(BILLIONS OF DOLLARS)

	Year 1973	Interval 1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
Resource						
Oil & Gas Exploration & Dev.	6.8	41.8	52.3	63.1	73.8	86.6
Uranium	.1	.4	.4	.2	.2	.2
Coal	.6	3.1	3.9	3.0	4.4	6.3
Oil Shale	-	.4	3.8	3.8	3.8	3.8
	7.5	45.7	60.4	70.1	82.2	96.9
Generation and Conversion						
Nuclear Power Plants	4.6[a]	27.5	21.8	16.7	11.9	6.8
Nuclear Fuel Fabrication		0	.1	.1	.1	.1
Nuclear Fuel Enrichment		1.6	1.1	2.2	1.1	2.2
Nuclear Fuel Reprocessing		.3	.3	.3	.3	.3
Fossil Fuel Power Plant	5.2	18.0	15.0	15.0	13.0	9.0
Solar	0	1.6	12.0	14.7	12.2	12.1
	9.8	49.0	50.3	49.0	38.6	30.5
Distribution						
Gas	3.0	30.4	25.8	14.4	5.0	3.0
Coal Transport	Not Avail.	2.1	2.0	1.7	1.8	2.0
Oil (Tankers & Pipeline)	1.5	9.2	2.4	2.3	2.4	2.3
Electric Trans. & Distrib.	7.8	24.4	30.9	37.5	43.7	50.0
	12.3	66.1	61.1	55.9	52.9	57.3
Total		161	172	175	174	185

a) 4.6 represents the sum of Nuclear Power Plants, Fabrication, Enrichment and Reprocessing.

for capital in the resource area. The main component of the resource area demand is oil and gas exploration and development. Although the importance of oil and gas to FTFB diminishes towards year 2000, the gas and oil available becomes much more expensive.

Of major concern is the large capital demand made by the supply areas. Whether these demands are realized remains to be seen. The impact of these demands is discussed in the next section.

Table 8-3 shows the major sub-areas which contribute to the supply resource, generation and conversion, and distribution areas. Capital needs are displayed for five year intervals. Examination of this table shows that, in the resource area, the capital requirements for uranium, oil shale, and coal are small compared to those required for oil and gas exploration and development.

8-2 FTFB IMPACTS

This section discusses the impacts that resource, manpower, material and capital requirements will create in the technical, environmental, economic and social/political areas.

8-2-1 END USE IMPACTS

The impacts that will be associated with the conservation ethic of the FTFB scenario are summarized in Table 8-4. In the FTFB scenario, conservation of various forms is used to reduce total consumption of energy from 183 Quads (historical growth projections) to 120 Quads by 2000. The Ford Foundation Report stated that this reduction could be accomplished by making consumption more efficient and making conservation the focal point of energy policy.

According to the report, the application of economically feasible energy saving "technical fixes" to the end uses of energy could reduce energy growth to 1.7 percent per year rather than the historical 3.4 percent. Critics of the report point out that the 3.4 percent historical growth rate used by the Ford Foundation is really not a valid assumption since this rate of growth is based on an average of the 1950-1972 period rather than the current energy growth rate. Current energy growth rate is a full percentage point higher than in the 1950's and 1960's.

The Ford report also contends that reductions in consumption could be obtained without reducing the standard of living or significantly changing lifestyles. (Critics question this assumption as well as the implication that energy not used in one sector can be readily transferred to another.)

The specified technical fixes which make the proposed energy savings possible in the FTFB scenario are included in the items listed in Table 8-4. Under the technological column heading, the negative indicates that technological advancement is needed to meet the energy requirements for the FTFB scenario; a zero indicates that the requirements can be met with existing

TABLE 8-4 FTFB IMPACT MATRIX: IMPACT AREA BY CONSERVATION PROPOSALS[a]

	Technological	Environmental	Economic	Social/Political
Smaller and/or more efficient cars, 25 mi./gal.	0	0	0	-
Increased air-craft efficiency and load factors	0	+	-	-
Shift short haul air travel to rail	0	+	-	-
Shift some inter-city freight to rail and more efficient trucks	0	+	-	-
Heat pumps	0	+	0	-
Process Steam	0	+	0	0
Metal recycling	0	+	0	0
Improved energy intensive processes	0	+	0	0
Better insulation and tighter const.	0	+	0	0
Total energy systems	0	+	0	0

a) Explanations of -; 0; and + are contained in the text of this section.

technology, although advances will probably facilitate the attainment of these requirements. Under the environmental heading, a negative indicates that meeting these requirements will probably result in environmental damage (of various kinds); zero indicates that no apparent effect on the environment will result.

Although the Ford report indicates that the "technical fix" solutions are both technically and economically feasible, it was felt that large scale introduction of these changes would have some impacts not mentioned in the report. As can be seen from Table 8-4, most of the technology for accomplishing these projected savings is available; however, it is expected that R & D efforts will result in improved efficiencies, which would increase the likelihood of obtaining such savings.

It is interesting to note that most of the energy conservation items listed by the Ford Report were felt to have either no effect or a positive effect on the environment. In other words, less pollution would result if these changes are instituted than if present conditions continue. For example, the introduction and increasing use of 25 mi/gal cars would not only result in fuel savings, but would also reduce air pollution. Increased aircraft efficiencies and load factors would also reduce air pollution since fewer flights would be required than now. Increased efficiencies in fuel consumption may also result in cleaner combustion.

Although converting short-haul air traffic to rail would not eliminate all pollution, it should reduce the level of air pollution from airplanes in addition to savings in energy consumption.

There are several perceived economic impacts in the FTFB scenario. In general, one can characterize these impacts as negative, neutral, or positive. Negative economic impacts are defined as extraordinary capital requirements, unemployment and higher costs to the consumer.

In the end use energy sector both positive and negative impacts result from the scenario. It is important to note that some of the negative impacts are super negatives, and they are direct outgrowths of the technical fix conservation proposals. For example, transferring short haul air passengers to rail and "some" intercity freight to rail is undoubtedly more energy efficient. However, such decisions call for planned unemployment (disemployment). Those disemployed are not necessarily transferable to other occupations. Shutting down short haul airline routes can be achieved, but the personnel involved cannot necessarily be transferred to other airline jobs since high load factors and fewer flights will result in fewer airline personnel.

Trucks haul a minority of the intercity freight tonnage, but to reduce its volume by half would require the displacement of a large number of employees. Many of the big rigs that roll the highways are also owner operated, some costing as much as $50,000. By shifting to rail the impact is likely to fall on these owner/operators and this would threaten their livelihood and way of life.

The requirements involved in transferring additional freight and passengers implies other economic impacts, expecially in hauling more passengers on the railroads. Many big Eastern U.S. railroads are now heavily supported by

government funds. To require that railroads invest in:

terminal facilities,

rolling stock,

extension of service to areas not now served,

improved track and track beds for high speed service, and

personnel to operate and service these new services,

is a burden that they are not likely to be able to carry. The requirements for providing such investments cannot be dismissed as problematical. If, for instance, the public sector is required to carry the financial burden of this investment, then it could lead to a demand for nationalization of the railroads.

Other economic impacts involve higher initial costs for the consumer, because of the technical fix requirements. Heat pumps, better insulation and tighter construction will require that the new-home buyer pay more for a home to achieve projected fuel savings. Improved energy intensive processes and total energy systems will also require greater first cost expenditure. Only if the tradeoffs are clear, with respect to the economic benefits of purchasing energy conserving technology, will these energy saving devices be installed.

Social and political impacts is a broad rubric which is inclusive of societal activities and their consequences if the FTFB proposals are implemented. The impacts are also characterized as negative, neutral and positive, but the estimation of impacts must be explained individually in some cases.

If government intervention occurs where it did not exist before, then the impact is characterized as negative. In addition undesirable effects caused by public policies required by the FTFB scenario, are characterized as negative impacts.

The decision elements that produce the most impact in the political area are those that involve deciding how rapidly to implement the scenario. Short lead times may require forcing change by authoritative decisions.

In the discussion of economic impact, some super negative impacts were identified. These super negative impacts have social and political as well as economic impacts. To disemploy people is a harsh action, and is philosophically counter to the philosophy of full employment. Groups in society that are without spokesmen can perhaps be ignored, but unions speaking for their membership seldom are. The truck drivers who protested high fuel prices in the spring of 1974 were not ignored, and their needs were rapidly met by government, both state and national. In that case government was required (some may say forced) to intervene to protect the interests of truck operators. If disemployment problems are a consequence of FTFB proposals, then they place the burdens on the political process to ameliorate their impact, or to reject the proposals. Delaying implementation only raises the probability of rejecting these conservation proposals.

The super negative impacts are problems that are essentially without discrete solutions, therefore they demand a thorough examination of the tradeoffs involved.

The other negative impacts are essentially those involving government intervention, e.g., the 25 mi/gal car and mandatory performance standards. The 25 mi/gal car is technologically viable, but it may be a less desirable product to produce or to buy. Mandatory performance standards is one means of reaching the scenario's conservation goals.

Mandated requirements in other areas can also be seen as a means of overcoming the resistance to change. Home builders can be required to install more expensive heat pumps and better insulation and to build tighter homes. The costs of these items will be passed on to the home buyer which may reduce the number of people who can afford to own a home.

Total energy systems, another FTFB proposal, may also require governmental interventions to make the system attractive for the builders of apartment complexes or commercial buildings. But as in other areas the mandate (governmental requirements for change) accelerates the rate of change and in many cases it would be necessary to achieve the scenario requirements.

Other government intervention can be used that are not mandates but incentives. These inventives could be tax breaks, e.g., depletion allowances. These incentives can come from all levels of government--Federal, State and Local, but in order to meet the requirements of the scenario the means of implementation should be acted upon soon to avoid compressing implementation into a narrow timeframe.

The technical fix proposals for conservation and other proposals in the FTFB scenario do not avoid political issues. Some of the FTFB proposals will only feed the fires of public debate. A final comment on the FTFB impacts, is that those areas that are characterized as having super negative impacts involve no technology. No technology is required to cut out short haul routes. No technology is required to shift freight from trucks to rail. They are basically social and political in nature.

8-2-2 ENERGY SECTOR IMPACTS

Some of the impacts associated with energy sector production, distribution, and consumption are common to all three scenarios. The common considerations are found in Table 8-5.

The technology for providing the oil, gas, coal, and uranium requirements for the FTFB scenario is available; however, improvements in present technology will result in an easier attainment of these goals. Advances and improvements in technology are needed for the protection of coal miners from respiratory and lung diseases (Appendix B-3-5). More advanced mining techniques are potentially able to reduce the number of workers needed in mines [Ford-74].

Some positive impacts may result from offshore exploration such as new dis-

TABLE 8-5 FTFB IMPACT MATRIX: IMPACT AREAS BY REQUIREMENT SECTORS[a]

	Technological	Environmental	Economic	Social/Political
Resources				
Coal	0	-	-	-
Oil	0	-	-	-
Gas	0	0	-	-
Uranium	0	0	-	-
Water	0	-	-	-
Manpower	0	-	0	-
Generation & Conversions				
Nuclear	0	-	-	-
Coal	-	-	-	-
Oil	-	-	-	0
Gas	0	0	-	0
Solar	0	0	-	0
Distribution				
Electricity	0	0	-	0
Coal	0	0	-	0
Oil	0	-	-	-
Gas	0	-	-	-

a) Explanations of -; 0; and + are found in the text of this section.

coveries of non-petroleum resources and new geophysical knowledge, that may be applied to geothermal energy development. An additional positive impact may be advanced fracturing techniques, for example, nuclear stimulation. These fracturing techniques may be of value in developing geothermal energy (Appendix B-1-4).

In the area of generation and conversion, existing technology can provide the required energy. However improved efficiencies and larger plant capacity factors can extend the lifetime of the natural resources being consumed to meet energy demands. Commercial introduction of breeders with breeding ratios greater than one can effectively increase the supply of fuel (see Section C-1-1).

On the other hand, maintaining air quality standards will require the perfection of air pollution abatement systems, such as sulfur dioxide scrubbers (or sulfur removal from coal prior to combustion), precipitators, etc.

Technological impacts in the energy distribution area will probably not be as important as in the AFTF and NEE scenarios. If slow and orderly growth occurs, then it is likely that few changes in technology will be required for achievement of this level of consumption. However, it is expected that research and development efforts in areas such as extra-high voltage transmission, circuit breaker technology, cryogenic underground transmission lines, coal slurry pipelines, etc., will make transmission of large quantities of energy more feasible in the future. A discussion of some of the anticipated impacts of these modes is presented in Appendix D-7-1.

Some of the environmental impacts that must be considered in the area of resources include the effects of strip mining, shale oil production, oil spills, and increased use of water.

Strip mining disturbs large areas of land; if these lands are not reclaimed (or restored), they are not only unpleasant to the eye, but no longer productive. An additional environmental problem associated with coal mining (both underground and surface mines), which has not yet been solved, is that of acid mine drainage (which results in contamination of surface and ground waters). Improved techniques for solving this problem are needed if coal is to be a major fuel for the generation of electricity or is to be available for converting to oil and gas.

The decision as to what must be done with the mountain of spent shale after the oil is extracted is a localized impact with serious environmental implications.

The debate over the long term biological effects of oil spills that result from drilling, recovery, and transportation activities is still under way. However, the immediate effects are evident: thousands of birds are destroyed, shellfish perish in large numbers, and beaches are made unfit for recreational activities. A great deal of effort in the research and development area is still needed to develop better technology for clearing oil spills. In addition, exploration and construction activities always involve

the possibility of ground water contamination. Additional discission of the impacts associated with the production of fossil fuels can be found in Appendix B.

In connection with the mining and milling of uranium, tailing ponds must be carefully planned and monitored to prevent disturbance of plant and animal life. In additions, water leaving the mines and mills must be monitored and carefully treated to remove radioactive material (see Appendix B-3-5). Constantly increasing demand for water may have serious environmental impacts. Large amounts of water are required in all of the resources extraction methods, in all phases; moreover gasification and liquefaction of coal require enormous amounts of water, three times as much as extraction of shale oil (see Appendix C-1-2, C-2-1, and C-2-2). The shortage of water is so critical in some areas that some proponents of coal slurry techniques and gasification schemes propose a water pipeline going in one direction with a slurry pipeline beside it going in the opposite direction.

The enormous quantity of water used by power plants (both fossil and nuclear) is also of concern. Of the 50 trillion gallons of cooling water used by U.S. industry in 1964, almost 41 trillion gallons-81 percent- was used for electric power plants. Discharge of this cooling water into streams or rivers results in thermal pollution. The environmental effects of thermal discharges are not fully understood. Raising ambient water temperature and altering the natural balance of aquatic life may degrade lakes, bays, estuaries, and rivers. Wet cooling towers have been proposed to eliminate the thermal pollution problem. However, wet cooling towers not only require land and material for construction but also lead to increased humidity in the immediate area from evaporative water losses. This water loss must be continually made up thereby reducing available water. Although dry cooling towers reduce the consumption of water and eliminate thermal pollution, they are not without problems of their own. Dry cooling towers for power plants require additional land as well as increased construction material and capital. The efficiency of the power plant would also be decreased by dry cooling towers.

Another environmental concern is the construction of dams to impound water supplies. The environmental impacts of these dams should be carefully considered.

An environmental problem in the area of generation and conversion is the release of sulfur dioxide and particulates during the combustion of coal and oil. Sulfur dioxide scrubbing techniques have not yet proved reliable and utilities have taken the position that under existing EPA standards they cannot supply the necessary energy with present technology. Other sulfur dioxide removal techniques such as the production of sulfuric acid or elemental sulfur are still in the developmental stage. Removal of particles a little smaller than about one micron in diameter is possible with current technology; however, smaller particles, which become visible as haze, cannot easily be removed with present technology. Evidence linking small particles to adverse health effects continues to grow. The interaction of these small particles with the sulfur dioxide in the air creates a health hazard worse than either acting independently (a synergistic effect). In addition, the small particles may also carry harmful trace elements such as Be, Cd, Zn, radio isotopes, etc. released during the combustion of coal and oil into the lungs. They may then enter the bloodstream

and interfere with body functions. Evidence linking sulfur dioxide to respiratory problems also continues to accumulate. The absence of means to prevent the release of these pollutants will result in a health impact as fossil fuel combustion increases. Therefore, technology to reduce the levels of sulfur dioxide and particulates in the air is a vital concern.

The use of nuclear fission power eliminates the problems of particulate and sulfur dioxide emissions but it poses serious problems with regard to reactor safety, radioactive waste management, and nuclear theft. Nuclear risks are qualitatively different from those of fossil fuel systems. Both produce thermal pollution: nuclear plants produce essentially no air pollution since their radioactive emissions are kept at low levels. However, nuclear power has unique problems and uncertainties associated with radioactivity. Disposal of radioactive waste is a problem of continuing concern. The licensing and regulatory responsibility for handling, storage, and disposal of radioactive wastes rests with the Atomic Energy Commission. Significant releases of these radioactive materials as a result of serious accidents could cause widespread contamination and the loss of many lives. Although the chances of accidents are low, the consequences of a serious accident would be significant and long-lasting. This balance of risk vs. benefit needs to be carefully scrutinized and must be settled soon if the nuclear option is to be viable.

An additional consideration in the use of nuclear fuel for generating electricity is the handling of the plutonium produced in the reactor. The potential for theft of nuclear material (plutonium in particular) and its use by criminal or political extremist groups to make atom bombs has been an area of concern. Present systems of guarding against theft appear to be inadequate. Appendix C-1-1 contains additional comments on impacts related to nuclear power.

Environmental impacts in energy distribution are more obvious; oil spills and disruption of the ecology by the Alaskan pipeline are lively concerns. Impacts associated with supertankers and LNG tankers are discussed in connection with other scenarios since the FTFB does not call for high imports of oil and gas. The impact of oil and gas transportation are addressed in Appendix D-7-2.

In the area of electrical transmission, noise pollution, land use, and visual pollution associated with high voltage lines can be mentioned. Another area of concern is obtaining additional right-of-way if advances in extra high voltage transmission do not materialize and present rights-of-way are insufficient. Acquisition of additional rights-of-way may present a problem in highly populated areas, where the demand for electricity is greatest. Additional impacts are discussed in Appendix D-7-2.

The increasing need for engineers, technicians, and craftsmen in the energy industry has been recognized by several groups of investigators, [Stewart-74] as well as the industry itself. However, the impacts of obtaining the required work force have not been addressed. In the environmental area, one might consider the impact of bringing 7,000 people to a small community to build a power plant. Some environmental disruptions are immediately evident. Inadequate water and sewer facilities are at the top of the list. The social disruption caused by this sudden influx of people must also be considered.

In the area of manpower, the problem of educating and training workers needed to provide the energy requirements of the scenario has not been addressed. Where, for example, do construction companies find engineers, electricians, pipefitters, welders, etc. needed for constructing power plants in the future? While the industry is working on the problem of providing the necessary craftsmen, by providing training programs for workers it is evident that assistance will be necessary. The number of engineers graduated each year is now below demand, and the demand for engineers in the energy industry will continue to increase. The adverse publicity resulting from unemployment of engineers in the aerospace industry in recent years must be overcome if engineering schools are to attract more students.

In the energy resources sector one finds particular negative impacts in the requirements for expanding oil and gas production. These requirements demand large investments in exploration, particularly in offshore drilling rigs. Expanding coal production and producing oil from shale is also a requirement of the FTFB. These also require large capital investments resulting in a large cumulative demand for capital.

One means of providing incentive for capital investment is to allow the prices of fuels to rise so that the return on investment also rises. In an energy intensive economy, allowing price to drive investment in exploration for resources can result in a continuing inflation. Such an overall impact can only be characterized as negative.

Other negative impacts in the generation and conversion and distribution sectors are negative, but not extraordinary; generally they would follow from the pressures exerted by the required growth in these sectors. In general the concern here is for those extraordinary impacts taht flow from the scenario requirements.

Political impacts are apparent in the FTFB scenario because they involve public policy debates that are not new. Coal, nuclear use and offshore drilling are not new policy issues. The environmental impacts have been discussed elsewhere, but the political impact of the demand for environmental protection cannot be ignored. In addition to the environmental issue, the expediting of resource exploration by Federal authorities is also an issue of continuing importance. The tradeoffs between environmental protection and expanded energy growth (even at a reduced rate) is a conflict that must be debated and resolved in the political arena.

Resource availability is another area of political conflict. If the FTFB scenario is to be achieved, it may be necessary for the Federal government to get involved in discovering (but not producing) oil and gas resources. Realistic information concerning resource availability, not educated guesses, would strengthen the hand of government if fuel allocations become necessary.

The Federal and State governments are also involved in labor relations. One of the difficulties perceived of expanding coal production is that coal supplies can be interrupted by strikes. If the interruption is sufficiently extended, government intervention will be required through mediation and mandatory cooling-off periods.

The generation of electricity by nuclear power is steeped in governmental regulation. The problems of siting, safety and fuel enrichment are issues which will continue to be in the political arena and power plant standardization is presently becoming an issue. The AEC has announced three standardization options which it is prepared to implement.

8-3 SCHEDULING/TRADEOFFS/DECISION POINTS FOR FTFB

It is possible to discuss Scheduling/Tradeoffs/Decision Points in two areas. One is the area of energy supply with its possible mixes, alternatives, and timing. The other area is energy demand or end use with its possible mixes, alternatives, and timing.

This task group has chosen to discuss end use of energy as it relates to FTFB. Energy supply for FTFB will be assumed to be similar enough to AFTF that a second discussion is not warranted. The supply material is covered in Section 9-3.

It appears that the options for tradeoffs and type of decisions concerning energy supply are similar for the two scenarios, given that the technological, political, social, and economic conditions are the same when a particular decision must be made.

The major difference in energy supply scheduling between the two scenarios is in the requirement to see that an adequate supply is available to meet the demands for the particular scenario (FTFB or AFTF). In order to meet the energy demand for AFTF and to entertain the possibility of reaching 2000 with zero energy growth at the same energy level as FTFB, it is necessary for the AFTF energy supply to be greater than that of FTFB for all years before 2000. In other words, the energy supply of FTFB is about the same as AFTF, but it is delayed in time by two to four years except near 2000. The conclusion is that anything that must be decided for AFTF and the options available to AFTF in the supply sector precede the same consideration in FTFB by two to four years. More time is available before FTFB must begin than for AFTF; but, once started, FTFB has the same timely decisions to make.

Imbedded in the FTFB as described in the Ford Preliminary Report are five energy saving mechanisms in the Transportation Sector, six in the Residential and Commercial Sector and four in the Industrial Sector [Ford-74]. Some of the mechanisms involve improved products and technologies; some involve shifts in modes of transportation; and some involve bringing into use technologies and practices which are not used today.

All of the energy saving mechanisms involve going from low level of usage today to one representing a measurable and significant energy savings at 2000. Several of the mechanisms also involve transferring from one energy consuming sector to another, e.g., inter-city freight from truck to rail.

In any event, the energy saving mechanisms start in FTFB at some low level and reach 2000 at a significant level. This implies phasing in new equipment or technology so that it is making sufficient energy savings impact at the year 2000. The question as to what is a reasonable phase-in time profile arises.

The task group chose a linear phase-in that would begin as soon as possible for a particular energy saving mechanism. This choice would lead to the least disruption to society. There are other possible phase-ins, but the linear phase-in seemed most practical and manageable.

The energy savings are often not without cost to society. The decline of truck usage means the need for trucks and truckers also declines. Hardships will result and individuals, such as owner/operators of truck rigs, will bear a disproportionate share of the transition cost. Possibly a wider goal than only energy conservation must be viewed. At least a more fully developed technological assessment must be performed than merely counting energy saved.

8-3-1 TRANSPORTATION SECTOR

The Ford Technical Fix Base Case scenario proposes several methods of reducing consumption in transportation which will result in a total saving of 16 quads of energy by 2000. The specific transportation conservation proposals are:

Smaller and more efficient cars, 25 mi/gal,

Increase aircraft efficiency and load factors,

Shift short haul air travel to rail,

Shift some intercity freight to rail and more efficient trucks.

Additional energy savings are included in an unspecified "other".

The 25 mi/gal car, proposed in the FTFB scenario, is an excellent example of the validity of assuming a linear path in moving from the present to the year 2000. If an historic growth pattern for the automobile is assumed, there will be approximately 160 million cars on the road by 2000. If all of these cars are 25 mi/gal cars then total fuel consumption would be no more than it is presently. This would lead to the conclusion that the present capacity in fuel production is sufficient to meet future needs, with only replacement for depreciated capital investment. If refining capacity does not need to be expanded, fuel consumption will be kept somewhat constant or below present requirements.

In the case of automobiles there is a tradeoff between a rapid and a gradual transition to 25 mi/gal cars. Around 1990 automobile manufacturers must be developing the final generation of cars to be produced in the late 1990's; production to start in 1994. These new units must be 25 mi/gal. cars (or better), or the scenario will not be met. Therefore, 1990 is a clear decision point. However, if 1994 is the start-up for production of the 25 mi/gal car, one can expect that no more than 50 percent of the cars will be 25 mi/gal cars by 2000, the average life of a car is about six years. If production were to start in 1994 and if the scenario is to be met, the phasing-out of pre-1994 cars must be accelerated and production of post-1994 cars must also be accelerated. Both conditions would be highly disruptive of the FTFB scenario.

The reverse can be examined if we assume that 90 percent of the cars on the road by 1985 will be 25 mi/gal cars. Technologically it is not impossible to meet this assumption, but it would require a high phase-out rate of pre-1978 cars (1978, first production of 25 mi/gal cars). It can also be seen that present refinery capacity would far exceed demand if 25 mi/gal cars were rapidly introduced after 1978.

It is clear that some flexibility does exist in the FTFB scenario as far as decision points and scheduling are concerned, if one is willing to accept the crunch that comes with a rapid phase-out. However, a more gradual transition to meet the requirement that 90 percent of the cars in 2000 be 25 mi/gal cars can be realized only if the decision is made "today" to begin production of these cars around 1985 while encouraging conservation of fuels by other means until 1985. If this occurs we can expect that 90 percent of the cars will be 25 mi/gal cars by 2000, assuming normal attrition.

Deciding now (1975) to produce the 25 mi/gal car in 1985 gives the auto producers a full development period, one generation (6 years) plus the production development time needed for full production (3-4 years). Such a plan of phasing-in 25 mi/gal cars after 1985 also allows these cars to go through one generation of development so that additional efficiencies can be gained, if possible.

Although precise schedules cannot be developed with respect to upgrading the railroads for expanded passenger services or phasing-out intercity truck freight, similar conclusions can be reached concerning scheduling and decision points. If investment in rail passenger service is delayed then a project of considerable magnitude is compressed into a narrow time frame.

The most severe problem in the airline and trucking industries is disemployment. To ameliorate the painful aspect of phasing-out intercity trucking and short haul airline routes, long lead times are demanded. This is particularly true of intercity trucking because this represents a way of life for a large number of people. The life of trucks is much longer than that of an automobile. Trucking therefore represents a monumental phase-out problem. If phasing-out is delayed, the severity of the problem increases and this increases the likelihood of scenario disruptions.

Rapid phase-out at tha front-end of the scenario is difficult for the same reasons, and is also likely to lead to scenario disruptions. The likelihood of disruptions, particularly in intercity trucking lies partly in the fact that, unlike the 25 mi/gal car, the phase-out of intercity trucking is not a technological problem. There is no technological involvement in phasing-out intercity trucking short haul airlines and transferring these transportation responsibilities to rail. These are public policy fixes which are primarily political decisions. The decision points, the scheduling of events and the tradeoff of impacts are therefore less clear. The decisions are more difficult to make.

8-3-2 RESIDENTIAL AND COMMERCIAL SECTOR

According to the Ford Foundation Report reducing the energy required to heat and cool homes and commercial buildings involves three different comple-

mentary approaches: improved building design and construction; more efficient systems for heating and cooling; and the use of renewable sources such as the sun. A breakdown of the approximate amount of energy that can be saved by the various approaches is shown in Table 8-6.

At first glance, more widespread use of insulation and double glazing combined with construction of "tighter" buildings to prevent outside air from leaking in appear to be a relatively simple, "painless" approach as to conservation. In fact, the technical and economic feasibility are demonstrable. However, a closer examination of these statements lead one to doubt that these savings can be achieved "painlessly". For example, implicit in the assumption that a certain amount of energy will be saved by this type of conservation is the requirement that a definite percentage of the buildings of the future will have this type of construction. A problem associated with this kind of assumption is the implications of its implementation. One is assuming that for some reason these homes and buildings have been equipped with these energy savings options.

Apparently, the prospects for energy savings in commercial buildings are good because the owners/operators will consider the savings in fuel costs. However, the situation may be different in the home market. Given the fact that good insulation and tighter construction is more expensive and that contractors try to reduce costs as much as possible, is it realistic to assume that these same builders will employ these initially more expensive methods simply because the savings will be greater for the owner when stretched out over a few years? This same kind of argument applies to the installation of heat pumps solar heating and cooling, and more efficient furnaces and air conditioners.

If this argument is valid, then how can conservation of this amount of energy be implemented? First, the rate structure could be changed so that conservation efforts are not penalized by increasing rates. Then an intensive education program might be undertaken to aid in the utilization of these conservation devices. All utilities would have to undergo a major change in emphasis; i.e., instead of encouraging additional use of energy as has been the case in the past, utilities would have to encourage conservation.

Some group or agency is needed to take the initiative (soon) in assuming the responsibility for educating banks, contractors, architects, as well as the public at large about the economic advantages of installing better insulation, heat pumps, more efficient furnaces and air conditioners, and solar heating and cooling in homes and commercial buildings. Perhaps pointing out that these devices for saving fuel can also save money in the long run, thereby adding to the value of the building, will be sufficient to stimulate savings in this area. An additional incentive may be the limited amount of fuel available. Utilities might be persuaded by a fuel shortage to persuade builders to incorporate these initially more expensive items.

In the event that construction starts within the next few years do not incorporate these energy saving methods which will probably indicate that the education program has failed, then some other kind of action will be necessary, if the scenario requirements are to be met. Some possible actions that might be considered include: tax incentives, adjustments in rate structures, and setting of performance standards.

TABLE 8- 6 RESIDENTIAL AND COMMERCIAL ENERGY SAVINGS [Ford-74]

Quads	Savings Area
5	Use of Heat Pumps
4	Better installation and higher construction
1	More efficient furnaces and air-conditioning
	Solar heating and cooling
1	Total energy systems
	Lighting improvement and design changes and water heating
16	

For example, if a homeowner is willing to install a solar heating and cooling unit on his house, property tax laws could be worded so that he would not be penalized for making this investment. In fact, offering an income tax deduction for implementation of conservation measures might be pumps (Appendix C-3). Assuming that rate structures have already been changed so as not to penalize conservation, additional conservation incentives might be gained by additional changes in rate structure (Appendix C-3).

Another possibility is the setting of performance standards in construction. In this event the architect and contractor would have to design and construct buildings that conform to certain performance standards that would reduce the consumption of fuel. A variety of options are open in this area. For example, highly efficient furnaces and air conditioners might be specified, heat pumps (in some areas), better insulation, double glazing and construction of "tighter" buildings might be required in all (or certain types of) building construction [TRW-74]. Perhaps the National Bureau of Standards (NBS) [Phillips-74] or a Consumer Protection Agency might be given the task of setting and supervising these performance standards. All housing involved in VA and FHA financing might be required to employ these conservation measures.

8-3-3 INDUSTRIAL SECTOR

The Ford Preliminary Report [Ford-74] indicates that 25 Quads of energy can be saved and must be saved in the industrial sector at 2000 if the FTFB is to be followed. It identifies four areas with the following savings:

More efficient steam production	13 Quads
Heat Pumps	
Combined electric/steam production	
Improved energy intensive processes	4 Quads
Metal recycling	2 Quads
Other (e.g. solar heating and cooling)	6 Quads
	25 Quads

The report further suggests methods of implementing the various identified energy saving techniques. Some are the following:

Market system oriented methods
- Full cost pricing
- Better market knowledge
- Subsidies to encourage saving mechanisms
- Taxes to encourage implementation
- Removal of depletion allowances
- Removal of regulations that do not encourage recycling

Non-market system oriented methods
- Regulatory measures such as performance standards
- Graduated taxes

The flexibility available in projected energy use mixes became apparent. With appropriate phase-in of energy savings end uses, an unlimited number of mixes become available. The point is that planning is necessary because timely choices must be made.

Once a certain energy savings mechanism is identified as one to be implemented and its year 2000 savings quantified, a count-back scheme can be used to determine the best possible time to begin implementation. An adequate warning time should be incorporated to allow industries to plan for the implementation. The only additional information necessary to determine the latest successful decision point is knowledge of the birth rate of the new mechanism and the death rate of any technology or equipment to be phased out.

Determining the latest successful decision point results in the most rapidly changing phase-in that is linear in response. If the decision point were earlier in time, a less rapid phase-in results and any resulting hardships are less important. Earlier phase-in decision points also allow energy savings which, in turn, allow delays in other mechanisms if necessary. Decision points should be identified as early as possible and mechanisms should be implemented as early as possible.

8-4 CONCLUSIONS ABOUT FTFB

The task group feels that FTFB can be implemented from a technological viewpoint. Strong concerns have arisen, however, with respect to how to manage changes which involve significantly altering or dismantling institutions within our way of life. Many of these institutions are strongly affected by social values which would have to change. If the final Ford Foundation Report does not address itself to this issue, a detailed assessment should be done to establish the validity of the FTFB path in terms of social cost. Another important consideration that needs to be addressed is whether the historical connection of energy-to-growth of the economy can be changed.

CHAPTER 9. ASSESSMENT OF THE AFTF PATH

This chapter contains an analysis of the Alternate path to the Ford Technical Fix Base case future at the year 2000 (AFTF) as defined in Chapter 7. The analysis is presented as an example of the methodology explained in Chapters 2, 3 and 4. The path requirements in terms of manpower, materials and capital are derived from the data base found in Appendices B through E and form the basis for the conclusions expressed here.

The AFTF path is the product of the thinking of the MEGASTAR group and not of the Ford Foundation. The energy source "mix" at the year 2000 is the same as for the Ford Technical Fix Base case but the path is one which leads to zero energy growth by that year. This presents an interesting study because of the impacts suggested by such a path.

As a basis for analysis, the AFTF path requirements are first summarized in a set of tables and graphs. Then the impacts, possible tradeoffs and cost benefits, and scheduling and decision points peculiar to the AFTF path are presented. Finally, the important features and implications of this path are summarized.

9-1 REQUIREMENTS

Appendices B through E each contain requirements for the implementation of the three paths presented as examples in this study. Appendix C, for example, contains requirements having to do with the generation and/or conversion of the various forms of energy specified by each path. The present section summarizes the requirements for the AFTF path by extracting pertinent data from all four appendices. The data are presented both in tabular and graphical form to enhance the reader's grasp of the elements of the AFTF path.

Table 9-1 gives manpower requirements from each of three segments of the energy industry: resources, generation and conversion, and distribution. Resources has to do with extracting fuels in their natural state - the mining of coal, drilling for oil, and so on. Generation and conversion deals with conversion between energy types - nuclear power plants, SNG plants, and conversion efficiencies. Distribution refers to the distribution or transportation of energy from source to user - electrical transmission lines, pipelines, and coal hauling. Engineering manpower is also portrayed graphically in Figure 9-1.

TABLE 9-1 AFTF MANPOWER REQUIREMENTS (THOUSANDS)

	1973[a]		1980		1985		1990		1995		2000	
	Engr.	Other	Engr.	Other	Engr.	Other	Engr.	Other	Engr.	Other	Engr.	Other
Resources	41	560	52	630	59	750	65	870	65	900	64	920
Gen. & Conv.	34	180	41	180	45	230	44	240	46	260	45	250
Distri-bution	21	660	35	740	38	750	38	760	34	700	30	570
Total	96	1400	128	1550	142	1730	147	1870	145	1860	139	1740

a) Requirements are for the (single) year 1973. Other columns are for five-year periods ending at the date given, except the single year values for 1973.

Similarly, Table 9-2 and Figure 9-2 give requirements for concrete and steel. Other materials were not tabulated, either because of insufficient data or because small amounts were called for and no potential bottlenecks or shortages were foreseen. As one example, between 1980 and 2000 approximately 50,000 tons per year of aluminum will be required for solar collector panels, but this is a small fraction of the total aluminum production and no other unusual aluminum demands were apparent. As an example of insufficient data, it was very difficult to assess copper requirements in the various segments of the energy industry. But copper production is currently lagging behind demand and future shortages are certainly possible.

Finally, capital requirements are shown in Table 9-3 and Figure 9-3 as an aid in assessing the economic impacts of the AFTF path.

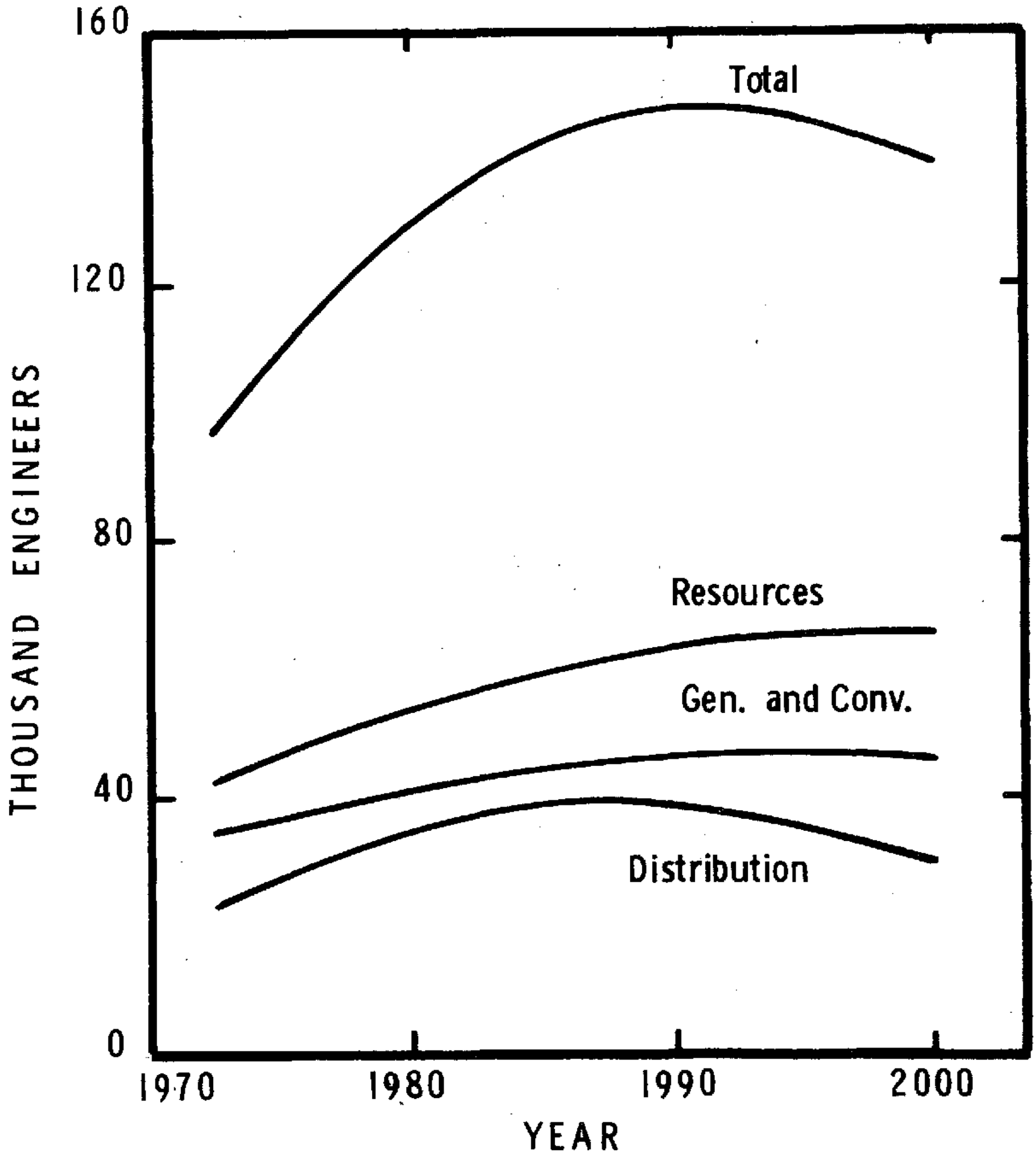

FIGURE 9-1 AFTF PATH ENGINEERING MANPOWER REQUIREMENTS

TABLE 9-2 AFTF CONCRETE AND STEEL REQUIREMENTS [a]

	1973 [b]		1980		1985		1990		1995		2000	
	Conc.	Steel	Conc.	Steel	Conc.	Steel	Conc.	Steel	Conc.	Steel	Conc.	Steel
Resource	8	8	49	51	56	59	60	63	67	69	77	78
Gen. & Conv.	2	1	6	3	8	4	7	3	6	3	6	2
Distribution	-	2	-	16	-	15	-	8	-	5	-	4
	10	11	55	70	64	78	67	74	73	77	83	84

TABLE 9-3 AFTF CAPITAL COST REQUIREMENTS
(BILLIONS OF DOLLARS)

	1973 [b]	1980	1985	1990	1995	2000
Resources	8	52	69	84	96	100
Gen. & Conv.	10	38	55	50	46	40
Distribution	12	76	79	68	57	24
Total	30	166	203	202	199	164

a) Steel in millions of tons, concrete in millions of cubic yards.

b) Requirements are for five-year periods ending at the date given except the single year values for 1973.

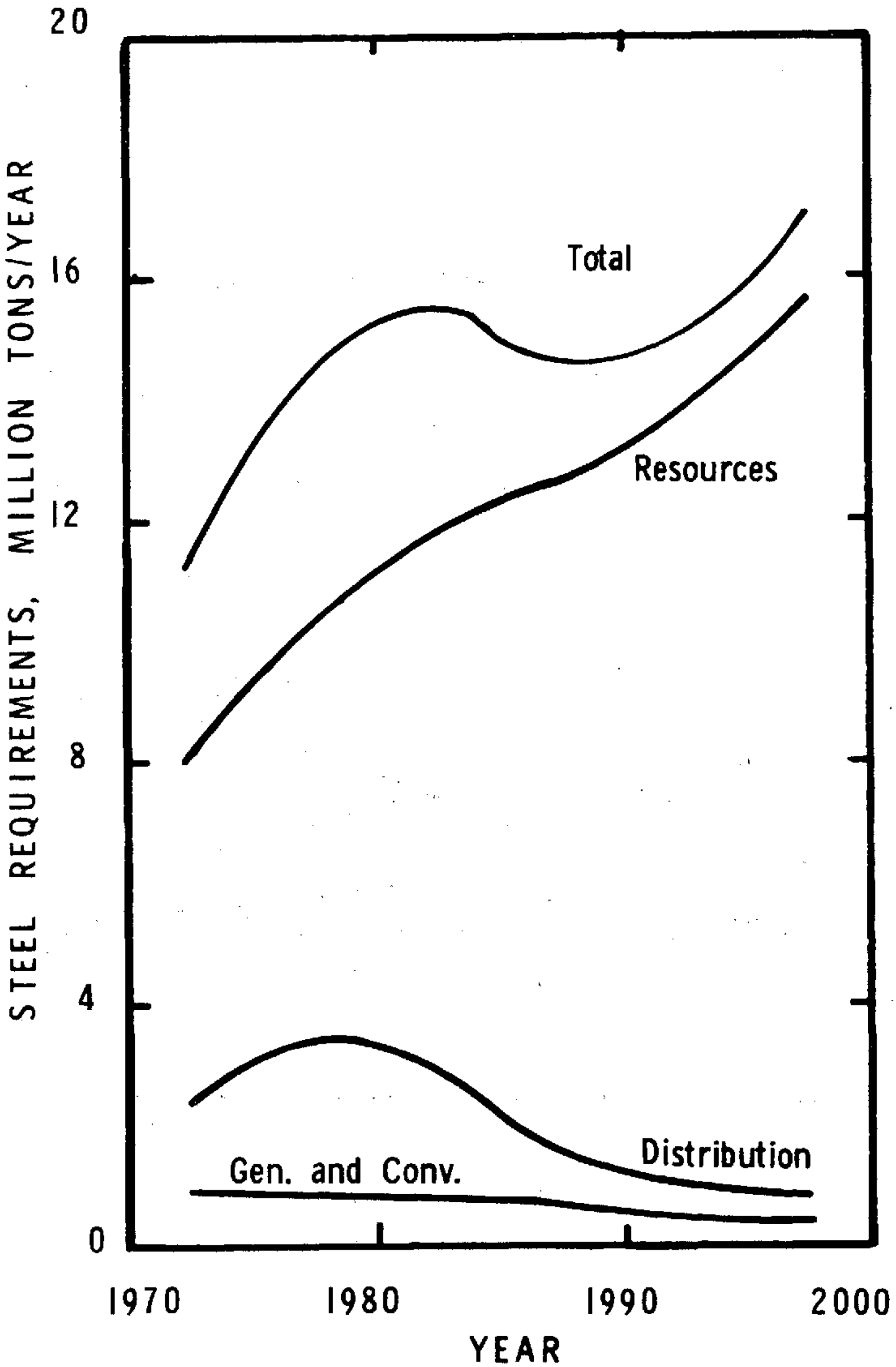

FIGURE 9-2 AFTF PATH STEEL REQUIREMENTS

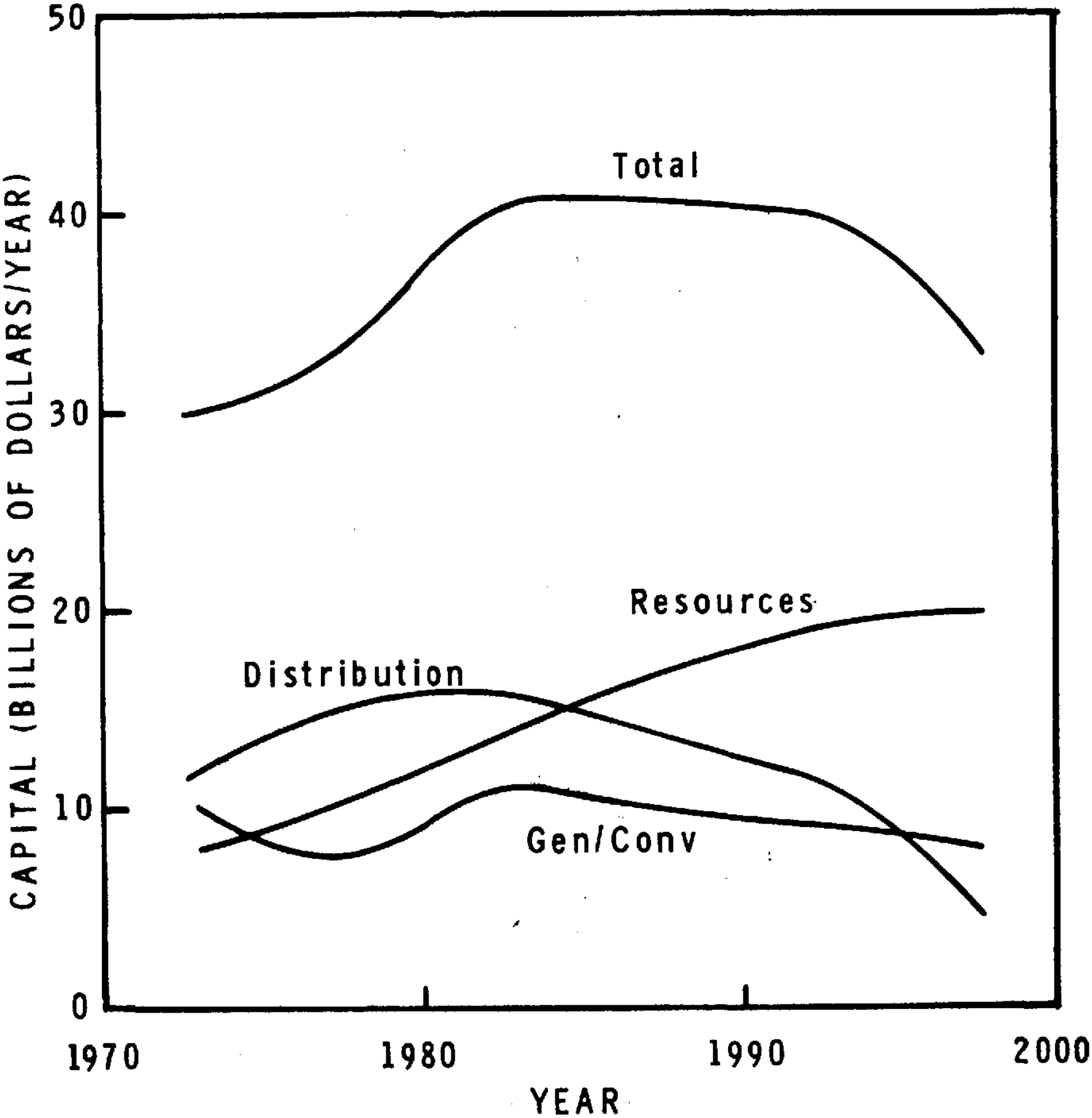

FIGURE 9-3 AFTF CAPITAL REQUIREMENTS

9-2 IMPACTS

Many different fuels are specified in the AFTF scenario, and impacts associated with the use of each fuel are detailed in Appendices B through E. In this section, those major impacts specifically associated with the AFTF scenario are discussed. These impacts are conveniently grouped into two areas: those directly related to fuel production, and those having to do with the end use of that fuel. Both Ford scenarios involve a great number of identical conservation measures. The end use impacts, which center around these conservation measures are discussed in Section 8-2 and are not repeated here. Thus, this section deals only with the technological, environmental, economic and social/political impacts associated with fuel production and power generation.

9-2-1 TECHNOLOGICAL IMPACTS

Coal

The rapid increase in coal usage will require an increase of 44 million tons per year (MTPY) in 1975 and an additional increase of 65 MTPY in 1976. Underground mines will supply 25 MTPY and strip mines 40 MTPY for the 1976 increase, which will continue to 1980, when the increase per year reaches 72 MTPY. Strip mine equipment is made by Bucyrus-Erie and Marion. The backlog of orders continues into 1977 and 1978, and indicates the presence of a serious equipment bottleneck.

Oil and Gas

The domestic oil and gas production for the AFTF scenario is dependent upon known reserves. There has been continual disagreement between the USGS and private oil companies as to the extent of unknown reserves. It will be difficult to maintain the prescribed growth in gas and oil or to approach tradeoffs and decisions without accurate knowledge of the resources.

The scenario depends on an increasing amount of shale oil. Impacts are evident here since the shale technology is just now developing. There is some question about the economy of shale oil which must be addressed. The conversion of coal to SNG and synthetic liquids are also very young technologies, which raise similar questions.

Nuclear

The nuclear segment of the AFTF path grows rapidly, even past 2000. If the breeder reactor has not been developed to the point where it can be brought on line by about 1990, it is possible that a U_3O_8 shortage could develop. Low grade uranium deposits would then have to be developed with a corresponding increase in fuel price. Also, the mining of lower grade ore requires more manpower and energy, compounding the problem.

Depending on the availability of U_3O_8, there may be more plutonium-fueled reactors in service. Since plutonium is considerably more dangerous

than uranium, transportation and reprocessing procedures will have to be carried out with even greater emphasis on safety if the probability of a serious accident is to be kept low.

Perhaps the most serious impact connected with a rapidly growing nuclear industry is the problem of containment and long term storage of high level waste products. Currently, the AEC has no provisions or plans extending beyond about 50 years.

9-2-2 ENVIRONMENTAL IMPACTS

Coal

Western strip mines are capable of perhaps 5 to 10 times higher per miner production levels than eastern underground mines. Also, the sulfur content of western coal is generally lower. But strip mining causes ecological damage which heals especially slowly in areas where annual rainfall is small and plant growth rates are low. Yet, eastern coal cannot be mined fast enough to satisfy the AFTF path beyond about 1976 and western strip mining will become necessary.

Acid mine drainage will be an increasing problem as existing mines are pressed into higher production rates. As coal is consumed at higher rates, toxic trace element air pollution (mercury, arsenic, selenium, etc.) will rise.

Oil and Gas

Several adverse environmental impacts are associated with the increased drilling and exploration necessary under the scenario. The nuclear rock fracturing plan for "loosening" impermeable oil-bearing rock layers will create local radioactivity. Secondary recovery by water injection has caused earthquakes. The increase in offshore oil activity will likely lead to more oil spills. Also, since oil imports increase until about 1980, spills from oil tankers are more likely. Finally, the small increase in refinery production may add to the existing air pollution.

North slope Alaskan oil will be carried to tankers with the pipeline currently being constructed in Alaska. A pipeline break would spill 800,000 bbl. [Campbell-74] and would cause extensive damage to the very fragile arctic ecosystem since typical tundra natural restoration times are of the order of 40 to 50 years.

Coal

The subject of limestone scrubbers could be presented as a technological impact because full scale scrubbers have not yet achieved satisfactory operation, but the effect is an environmental one. Scrubber technology will almost surely become reliable and effective in the near future; but until then, the burning of coal will create a great amount of air pollution. And even then, there will remain the problem of disposing of the large amounts of sludge produced by the scrubbers.

Nuclear

There are possible environmental impacts connected with the nuclear segment, mostly dealing with transportation of radioactive materials and various types of accidents. These are summarized in Section C-1-1.

9-2-3 ECONOMIC IMPACTS

Coal

Many new coal mines will be needed to replace depleted mines and to meet the rising AFTF coal demands. But no mine will open without, at least a 20 year contract for the mine output. Thus the coal industry must have assurance of continuing markets. As to the rate of opening new mines, the scenario calls for the opening of 35 - 40 mines per year in 1976 which is perhaps 10 times the current expansion rate and will involve great changes in the industry. A coal strike predicted for late 1974 complicates the rapid expansion needed to "get on" the AFTF path.

Oil and Gas

Figures 9-2 and 9-3 show that the resources segment of the energy industry has steadily increasing material and capital requirements even beyond 2000. This reflects the continuing exploration and production efforts necessary to meet the oil and gas demands. These demands decrease beyond 1990, but presumably oil and gas are becoming harder to find. Thus, the petroleum industry will continue to constitute a large fraction of energy expenditures through the year 2000 and beyond.

Natural gas imports must rise to nearly four times the present level by 1987. Thus, a number of large LNG tankers must be built. Beyond 1987 gas imports decrease slowly to just above present levels at the year 2000, possibly leaving the U. S. with a fleet of worthless LNG tankers. However, these tankers can probably be used to transport LNG profitably between foreign countries.

Nuclear

There seem to be no serious economic impacts associated specifically with the AFTF nuclear requirement. More capital is required in the resources (mostly coal and petroleum production) and energy distribution segments than in generation and conversion which includes the building of nuclear plants and supporting facilities. A major factor in depressing nuclear capital requirements is the possibility of standardizing nuclear power plants, and the orderly expansion prescribed by the AFTF path.

General

As Figure 9-3 shows, there is a sharp drop in the total capital required by the energy sector of the U. S. economy starting in the early 1990's.

This is not a negative impact in the normal sense, but it suggests a number of other major effects which are characteristic of ZEG. These effects are addressed in Section 9-3-4.

9-2-4 SOCIAL/POLITICAL IMPACTS

Coal

The strip mining bill HR11500, if passed, will likely curtail new strip mines in the west. With Western coal difficult to obtain, the use of more expensive Eastern underground coal is an alternative. However, the Clean Air Act of 1970 does not favor Eastern coal with its high sulfur. With the Federal limitations on Eastern and Western coal, the smaller mines may provide some capacity for added coal needs. But the coal mines Health and Safety Act of 1969 has already resulted in production slowdown of perhaps 20 percent in these mines. In summary, the present political climate is not one which would encourage the needed coal production expansion.

Oil and Gas

The expansion in domestic oil and gas production in the AFTF scenario will require rather deliberate national efforts. Incentives to spur exploration will be needed, particularly for gas. The first obvious move would be gas price deregulation.

Nuclear

The rapid expansion of nuclear power generation could be halted by a single, serious accident. Social pressure could create a moritorium on plant construction. In the event of a serious accident, the $500 million liability coverage provided the utilities by the Federal government may not cover medical expenses, loss of income and various damages which might occur.

The rapid growth of the nuclear industry (beginning immediately) has the potential for the creation of a serious manpower shortage. Graduating nuclear engineers, particularly, will not be sufficient. It may be necessary to instigate special training centers for operators and technicians in the nuclear field. In fact, all types of engineers will be in short supply. It is not simply a matter of expanding universities rapidly (even if it were possible). Though many new engineers are needed between now and 1985, very little manpower growth is needed thereafter. Thus, the (newly expanded) university programs must again contract.

9-3 SCHEDULES/DECISION POINTS/TRADEOFFS

The purpose of this section is to identify major decision periods and assessment areas that will be needed to implement the AFTF scenario, both now and in the future. The assessments are limited to those energy sources that dominate the fuel mix within the scenario. Decision points are necessary in order to attain the scenario objectives with respect to specific fuels and to overall fuel mix. Each of the major fuel components is traced throughout the time period of the scenario, and decision points peculiar to each fuel are examined. Next, the potential interfuel tradeoffs are discussed with respect to possible under or over-supply of the various fuels. Finally, the decisions that must be made now in order to initialize the scenario are explained.

Schedules, decisions and tradeoffs dealing with the conservation measures specified by both Ford scenarios are covered in Section 8-3. Those discussed here have to do with fuel sources, not end use of fuel.

9-3-1 FUEL SOURCE SCHEDULES

Oil and Gas

The dominant energy source within the AFTF scenario is domestic oil and gas, both of which must increase approximately 50 percent by the year 1990. For these fuels the basic problem is finding new wells and bringing them into production, as opposed to the projected increases in coal use for which the basic problem is to create guaranteed long-term demand.

The increases in domestic oil and gas production must be achieved in spite of recent drops in production and in new discoveries. In 1971-72, oil and gas production held essentially level and in 1973 production actually dropped. But in the most recent reports, there is considerably increased on-shore drilling activity. The major reason for these increases is the significantly higher market price of oil since the Arab oil embargo of 1973-74. Short-term bottlenecks to expansion of on-shore exploration and development include certain iron and steel products and poor distribution of various tubular goods (see Appendix B-1). In view of current drilling activity and the fact that the Alaskan pipeline will begin operation by 1978, it appears that the domestic oil and gas needs in the scenario through about 1980 can be met.

Beyond 1980, increased off-shore production of both oil and gas is essential to meet the scenario goals. Bottlenecks in the development of off-shore oil are illustrated in Figure B-3. The most important problems are public concern about environmental quality and government concern about rational development of the resource base. Additional drilling equipment will also be needed. Currently, drilling equipment built in the U. S. is being diverted to foreign markets; e.g., the North Sea.

Decisions needed now that affect domestic off-shore drilling and production are discussed in Section 9-3-4. If these decisions do not stimulate off-shore production enough to make domestic oil competitive with imports, then the years around 1980 will feature trade-offs between domestic and imported oil. The trade-offs will be between low cost imports, with continued vulnerability to foreign political decisions, and higher cost domestic oil. But other trade-offs are possible. By relaxing environmental standards, it will be possible to increase on-shore production via enhanced recovery methods, and off shore production by accepting increased oil spills. For example, the Santa Barbara Channel can be reopened. There are wells in this area, sitting atop proved reserves of 3 billion barrels - but the wells are capped and are not producing as a result of the massive oil spill which occurred in 1969.

The period around 1990 is particularly critical for the AFTF scenario. Eventually, oil discoveries and production will begin to turn down. The precise timing of this turnover depends on a great number of factors, one of which - the physical limit of oil in the earth - cannot be denied. It may well be, as Professor Houthakker of Harvard University suggested in a seminar held by this study group, that the recovery of oil is limited, within the foreseeable future, only by economics: the higher the price, the more oil will be found. Whatever the cause, the turnover may occur around 1990, as envisioned in the AFTF scenario. On the other hand, the peak in production may occur much later. Should this be the case, there will be at least three options available. First, the remainder of the AFTF scenario could be ignored, and oil use simply continued at a constant or increasing rate. Second, it could be decided that oil and gas reserves are too valuable to use up as a source of energy - that oil should be conserved for use as feedstocks for industrial processes. In this case, government action will be required to limit production. Such action would require continued public commitment to the ZEG goal embodied in the AFTF scenario. The third option would be to obtain a greater portion of the energy in the AFTF scenario from petroleum and less from other sources.

Up to this point, oil and gas have been treated together because oil and gas are usually found in the same wells. However, new geological techniques are beginning to reveal gas resources that do not occur with oil. Consequently separate incentives may be required in order to achieve the gas expected in this scenario, such as deregulating gas prices. Increased gas importation will be possible if domestic gas supplies are insufficient. Additional gas tradeoffs are considered in Section 9-3-2.

Coal

Within the AFTF scenario, coal production is envisioned to increase from approximately 11 Quads per year to 25 Quads per year by 1990. The reason for this projected increase is simple: coal is our most plentiful fossil fuel resource and its recovery is technologically simple.

Within the first few years of the scenario, increased coal production can be achieved by simply increasing the number of man-hours per week that coal mines are worked; a 10 percent production increase can be obtained in this fashion. In the longer run, there must also be a large number of new mines opened. The major problem here is that opening new large coal mines requires capital and assured long-term markets. But strip coal mining, which requires less capital and less lead time before production, has already been restricted by Congress. The House of Representatives passed HR 11500 which provides for much more land reclamation and recovery than has been the practice of coal miners. The final form of this bill is unknown, but there is general agreement that strip mining in the western states, where most of the United States' strippable coal is located, would be reduced. More importantly, EPA regulations on air pollution standards have made the generation of power from coal less attractive. Both these effects detract from an expansion of coal usage. The major incentive for the construction of coal-fired power plants is that coal will be available for a long time.

Beyond 1980, coal will be more attractive than today. Air pollution control technology will surely have made possible the burning of available coal. The mining industry will have learned what is required to operate within legislated constraints of land and water environmental standards.

Assessments during the 1980's involve advancing air pollution technology and new power generation efficiencies through topping cycles. Topping cycle technology is a part of the AFTF philosophy; if the trade-off between increased installation and decreased operating costs is uneconomic, government policy decisions will be needed.

Nuclear

The nuclear power generation projected for 1980 within the AFTF scenario is consistent with this task group's assessment of the generation and conversion industry. This assessment is in contrast with AEC projections which are constantly being revised downward. During the early 1980's, questions on waste disposal and environmental hazards (as discussed in Appendix C) will have to be answered. These answers will determine whether nuclear power will continue to increase, taking over a large fraction of power generation as prescribed in the scenario - or whether nuclear power will be retarded and coal generated electric power increased. This determination must be made no later than the mid-1980's because decisions will then have to be made that commit the country to an economy based on nuclear electrical power generation. Data adverse to nuclear expansion will not necessarily be fatal to the concept of the AFTF scenario, because electrical generation based on increasing amounts of coal can continue. (The end use sector of the economy, which does not depend on the particular electrical power generation fuel, is discussed in Chapter 8.)

Significant information on breeder reactors will be available in the 1990's. This information is not critical for the AFTF scenario, however, because the amount of power required from nuclear generation can be supplied from conventional light water reactors even beyond 2000. Commercial success of the breeder will degrade the importance of ZEG for the 21st century United States.

Several potential occurrences overhang the nuclear segment of this or any other scenario. Release of large amounts of radioactive material, either by accident or by the overt actions of anti-social groups, would have grave consequences. A moratorium before 1985 on nuclear power generation, whether temporary or permanent, would slow down the growth of nuclear power while security measures are reassessed and public concern tempered. After 1985, a moratorium would significantly change life style while nuclear capacity is shut down or is being replaced.

9-3-2 INTERFUEL TRADE-OFFS

Implicit in the definitions of both AFTF and FTFB scenarios are the options of leaving some fuels undeveloped relative to production levels that could be achieved with an all-out effort. The Nuclear Electric Economy constitutes a vigorous effort, and does not provide much flexibility in development of fuel supplies. The purpose of this section is to examine the various interfuel trade-offs that may become available at future dates under the AFTF scenario. The basic trade-offs considered are coal/nuclear for generation of electricity, domestic/imported oil, and domestic/imports/shale oil/synthetic fuels from coal for direct and feedstock use.

The earliest trade-off (one which is occurring now) is between imported and domestic oil. Within the AFTF scenario, imported oil increases slightly to 1980 and then declines to zero in 1990. The value of this trade-off has been suggested above. It should be pointed out that this could well be a net zero of oil imports, rather than a gross zero. It will no doubt prove cheaper in the indefinite future for the Eastern United States to get its oil from either the Middle East or Venezuela; exports of oil from Alaska to Japan could reduce the net imports to zero. The reduction of gross oil imports to zero may be unnecessary and unwise. Arab oil is at present the cheapest energy source in the world in spite of transportation costs; the United States is not likely to completely forego the economic advantages of using it. If domestic oil reserves sufficient to meet the needs of the scenario are proved up, then the risks of reliance on imported oil are minimized, and there is no reason to arbitrarily eliminate all imports. In fact, continued importation at a reasonable level allows the United States to maintain its economic and political influence throughout the world.

Much more serious problems arise if domestic oil reserves cannot be found to meet the requirements of the scenario. In this case, the options are to rely on imports with the corresponding risks, to use less energy in an economy in which conservation is already nearly

maximal, or to develop more aggressively synthetic and shale oil supplies and to accept the environmental hazards involved. Reliance on imports must continue until about 1980, at which time information on off-shore reserves should be available and shale/synthetic options are better understood.

In the late 1980's, options for coal versus nuclear generation of power become available, as discussed above in the description of nuclear goals. If both coal and nuclear options can be exercised, there is the danger that the small, uneconomical, developmental energy sources will be ignored. These small energy sources (e.g., solar and geothermal) may be attractive for post-2000 energy resources.

By the mid-1980's the conservation measures explicit in the technical fix scenarios should have been implemented. The success of these measures must then be assessed. If the energy savings are not as great as anticipated, the scenarios will have to be modified in the direction of increased energy production or sacrifices in life style. In this sense, conservation is a fuel source and success at conservation implementation is equivalent to the development of a fuel resource.

In the 1990's, the potential economic hazards of ZEG will become apparent, because per capita energy growth will be decreasing. If the United States then has extra energy available, the extent to which ZEG is actually implemented will become a matter of debate. The long-term social benefits must be weighed against the short-term economic dislocations involved in the transition to ZEG, dislocations which will be much better understood at that time. Section 9-3-4 discusses various aspects of ZEG.

9-3-3 DECISIONS REQUIRED NOW

Decisions are needed now or in the near future in order that the first steps of the scenario can be achieved. They range from incentives to the oil and gas industries, to setting licensing procedures for nuclear energy and air pollution standards for the coal industry. The decisions needed are discussed below for each fuel separately.

For the most part, on-shore drilling for oil is being expanded at a pace sufficient to meet the scenario. There is one apparent bottle-neck in the distribution of tubular steel stock items: small independent wildcatters claim that the big companies have hoarded the supplies. Government action, to facilitate distribution, might further spur on-shore drilling.

In order to meet the scenario, off-shore exploration and drilling is also essential. The government should plan regular off-shore lease sales in the future. Lease sales could be made more attractive by changing the sale requirements. At present, the entire price must be paid at the time of the sale, and this requirement ties up capital which could otherwise be spent on drilling equipment and operations.

Part of the reason off-shore drilling is critical is that many energy related decisions, to be made in the future, depend on knowledge of the domestic oil resource base. There are two ways the government can act to gain the essential knowledge. First, the government can set up a monitoring system for all resources on Federal land, and in particular for off-shore oil leases. (At present, the government does not require oil companies to provide detailed information on the mineral content of leased Federal lands.) Second, the government could itself carry out a detailed resource base survey of off-shore areas, including those in which no drilling has yet taken place; e.g., the Gulf of Alaska and the Atlantic Ocean outer continental shelves. A large part of the survey could be done using new technologies which require relatively little actual drilling. Such technologies will add a great deal of information on potential sources, but will not increase proved reserves.

Incentives for the gas industry may be needed, separate from the incentives for oil exploration. The incentive most discussed by the AGA is deregulation of gas well-head prices. Such deregulation will, of course, lead to higher gas prices and increased exploration. But in addition, higher gas prices will spur the development of the solar heating and cooling segment of energy use. At the present time, solar heat is generally competitive with electric resistive heating but not with gas heating; deregulation of gas prices will make solar heating and cooling systems more competitive. (For details on solar heating and cooling, see Appendix C-3.)

Coal is an important part of the scenario, but immediate increased use is limited by environmental constraints and cost and supply uncertainties. Air quality standards and mining standards are both in flux as the result of national debate over environmental quality and miner health and safety. In addition, a major coal strike is expected in November which, if prolonged, might lead to uncertainty about how assured coal supplies will be in the future. Decisions are needed now, that will convince utilities that they can operate within future cost/supply conditions.

Present air quality standards, applied rigorously in 1975, will probably cause many coal power plants to shut down because present emission controls are unreliable - and in many cases not installed. Decisions needed now include:

> Setting intermittent standards that allow emissions higher than present standards under appropriate atmospheric conditions.
>
> Intensifying efforts to develop reliable emission control equipment.
>
> Making provision for protecting utility company investments, in the face of future changes in emission standards.

These decisions should make construction of new coal-fired plants more attractive.

The major impediments to nuclear power plant construction are long lead times caused by delays in component delivery, labor problems, and the time required to evaluate new sites. Construction and delivery of components can be speeded up if standardization of components is allowed. Modification of present anti-trust legislation is needed before standardization can be accomplished. Labor problems are beyond the scope of this report. The evaluation of new sites could be expedited by the government. A comprehensive program could be started to evaluate potential sites and prepare preliminary environmental impact statements appropriate to each site; a similar program is already carried out for hydroelectric power.

Another limitation to the expansion of nuclear power generation is the possible shortage of enriched uranium in the early 1980's. Present enrichment capacity is committed; the AEC is not accepting new contracts for fuel deliveries. The decision needed now is whether government or private industry will construct future enrichment facilities.

9-3-4 ZEG ASPECTS OF AFTF

The most important difference between AFTF and FTFB is that AFTF reaches the year 2000 with a Zero Energy Growth economy. The reasons for accomplishing a ZEG have been discussed by the Energy Policy Project [Ford-74]. The purpose of this section is to examine how the path of the AFTF scenario can be used to achieve ZEG, and to examine the impacts involved in implementing the transition to a ZEG society. The assumption on which this section is based is that society chooses ZEG rather than continued growth, even though continued energy growth may be physically possible.

The structure of a ZEG economy will be significantly different from the present, and many of its features will be unpalatable to most Americans. The discussion here should not be construed as a brief in favor of ZEG, but simply as an assessment. To begin, some features of a ZEG economy are listed below.

> Conservation will probably be mandated; strict enforcement will be necessary.
>
> Mobility between segments of the society mean that as one group increases its use of energy, other groups must reduce theirs. A more rigid stratification of society may result.
>
> The economy may stagnate; new industries and technological advance may be stifled because of limited energy production capacity.
>
> Fixed limit on energy use may result in an upper limit on exports. Consequently, other countries with positive energy growth may eventually surpass and dominate U.S. products in world markets.

Surplus energy production capacity that can be turned on rapidly will be needed to provide for emergencies and to provide energy for changes in longer term goals. (ZEG is perceived as a several year average ZEG.)

Broad-scale government analysis and planning is essential. Single facets of problems cannot be attacked, but rather the impacts of decisions on the entire society will have to be considered. This is illustrated by an analogy to the "energy bank" mentioned above: for years, the soil bank program provided excess agricultural capacity, but when increased agricultural production was needed, tractors were not available in sufficient numbers. An energy bank could run into the same kind of difficulty.

It will be necessary to express disposable income in new ways that do not require large quantities of per capita energy. For example, the service segment of society will certainly be much larger, again tending to stratify society.

The transition to ZEG will be difficult. Much of the planning must begin now or in the next few years, so that at least one generation will grow up becoming accustomed to the necessary constraints. Accomplishing the transition will require a lot of interaction between government and industrial leaders, and public debate and education. Society will have to learn to tolerate high fuel prices and excess domestic capacity. High fuel prices reflecting "full social cost" will be an important factor in accomplishing the transition, particularly during the 1990's. These high prices will be maintained by mandating that excess capacity not be produced.

The AFTF scenario has more energy production capacity between the present and the year 2000 than does the FTFB scenario, but the savings from conservation are just as great. Most of this extra energy is to be used in preparation for ZEG; some examples of this preparation include:

Retrofit of inefficient equipment; e.g., storm windows on houses and buildings, and elimination of "reheat" space conditioning.

Design and building of new, more efficient equipment; e.g., the conversion to electric cars.

Mass transit improvements and construction, both for commuter and intercity traffic.

Relocation of factories, homes, and commercial buildings into contiguous communities, reducing transportation and other energy needs of daily life.

Construction of automated services, to reduce transportation needs; e.g., automated stores, from which orders are made by "visiphones". More generally, low priority transportation will be replaced by electronic communication.

It should be pointed out that even with the best planning, the impacts on society of ZEG will remain unclear until ZEG is actually attempted. Small scale model experiments (e. g., on a community-wide basis) would not adequately reflect the complexities of the entire United States. The ZEG society appears, from the 1974 perspective, to be revolutionary. Hopefully a revolution would not be necessary to achieve it.

9-4 CONCLUSIONS

In terms of gross energy consumption the NEE path is almost an extention of historical energy use. In contrast the AFTF path, which calls for immediate expansion in nearly all domestic energy industries, is not a historical path. To offset a fast reduction in oil imports, domestic oil, gas, coal and nuclear power generation must expand rapidly, and the advanced forms (solar, geothermal) more slowly. Then, as the year 2000 approaches, some segments of the economy must backpedal to slow the overall growth rate to zero. The U. S. has faced rapid expansion before, such as during World Wars I and II which was accomplished only by strict governmental invervention. However, a deliberate nationwide economic slowdown has never been attempted. It seems clear that a commitment to follow the AFTF path would also be a commitment to greatly increased governmental control.

All of the impacts and characteristics of the AFTF path discussed in this chapter have a central theme: They either deal directly with ZEG or with events preparing for ZEG. It is for this reason that section 9-3-4 is included. The idea of ZEG is appealing to some, particularly if the population growth rate continues to decline. While the AFTF path achieves ZEG, it may be that the transition is too abrupt. Perhaps 50 years is a more reasonable period in which to attain ZEG. The painful expansions and contractions seen for the economy along the AFTF path would be greatly lessened by lengthening the transition period.

In this chapter, philosophical questions regarding the desirability of ZEG have not been addressed. The assessment of the AFTF path was conducted without questioning that desirability. The question of the desirability of ZEG is discussed in Section 11-6-2.

CHAPTER 10. THE NUCLEAR ELECTRIC ECONOMY

The paths discussed in Chapters 8 and 9 emphasize conservation. The Nuclear Electric Economy which will by analyzed in this chapter emphasized meeting anticipated demand which is assumed to be a projection of historical demand.

10-1 INTRODUCTION

The Nuclear Electric Economy (NEE) is characterized by a transition to electricity together with decreasing dependence on gas and oil. Energy growth is postulated to continue at the historical rate of four percent per year. Coal use in the NEE scenario increases to six times the present usage by the year 2000, when 40 percent of the coal will be used to make synthetic gas and oil. The total installed electrical capacity will be about 2300 GWe, of which 1400 GWe is nuclear (including 230 GWe in Liquid Metal Fast Breeder Reactors), and 860 GWe is fossil-fired. By the end of the century, it is assumed that nuclear capacity will be growing at a constant rate of approximately 100 GWe per year, of which one-third will be LMFBR's [AEC-74-3]. Thus, in this scenario, nuclear power grows from 27 GWe now to 51 times as much in 2000, while fossil-fired generators approximately double. At 2000, fossil capacity is no longer growing.

The electric power available to American industries and consumers in the year 2000 will be about five times the present level. Meanwhile, the population will have grown from 210 million to 255 million [BUS WK-73]. Some pronounced changes in energy consumption are called for: electric heat pumps for heating and cooling, electric trains and automobiles, electrified processes for industry, and more electric machines. Oil and gas consumption in the year 2000, including synthetic fuels, would be down slightly (-7 percent for oil, -20 percent for gas) below current consumption. Gasoline consumption would be down 70 percent.

10-2 PATH REQUIREMENTS

It will require a large effort for the country to implement the NEE. The investment capital requirements are summarized in Fig. 10.1 and Table 10-1 (See Appendices B - D for details). The significance of these capital requirements is pointed out in a recent analysis [AIF-73] of the future needs of the electric utility industry. Interpolating to match the NEE scenario's capacity, and assuming a price of 2.5 ¢/kWH it appears that, between now and 1990, the total gross income of the utilities will be $1650 billion. If the utilities set aside 15.3 percent of their gross operating revenues to pay for expansion, $250 billion of this will be retained earnings, which is 36 percent of their capital requirement. The other 64 percent ($450 billion) will have to be raised in the money market.

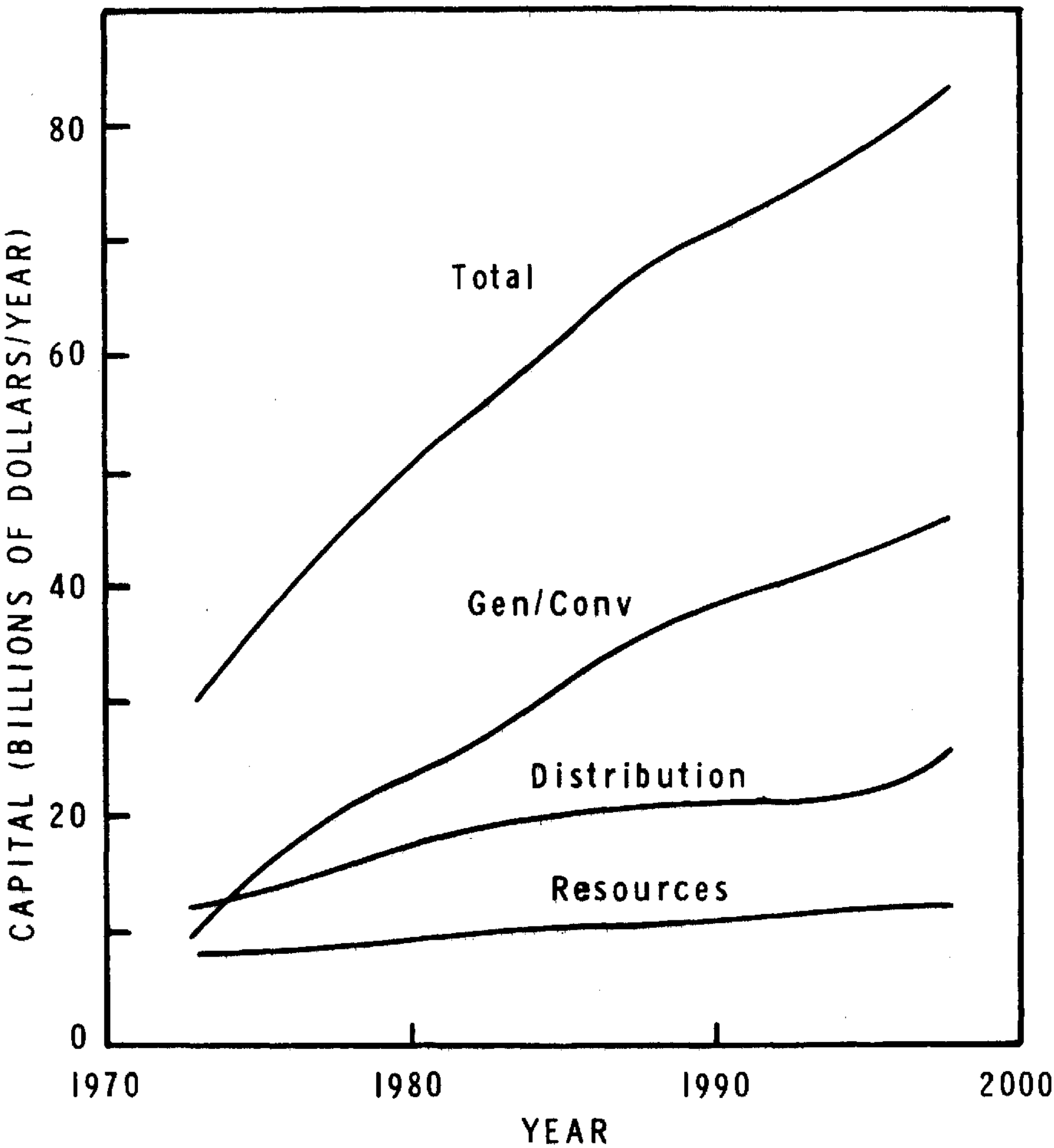

FIGURE 10-1 CAPITAL REQUIREMENTS FOR THE NUCLEAR ELECTRIC ECONOMY

TABLE 10-1 CAPITAL REQUIREMENTS FOR THE NUCLEAR ELECTRIC ECONOMY (BILLIONS $)

Time Period	(Present)[a] 1973	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
Resources	$ 8	$ 43 [b]	$ 49	$ 53	$ 58	$ 60
Gen/Conv.	$10	$101	$136	$179	$205	$230
Distribution	$12	$ 78	$ 94	$105	$108	$124
Totals	$30	$220	$279	$337	$371	$ 414

a) Requirement is for five-year periods except the single year values for 1973.

b) Decrease in resources expenditure due to slowdown in oil.

The manpower required to build and support the NEE is large compared to the other two scenarios examined in this report. The number of engineers in the energy industry must approximately triple from the current level of 105,000. This presumes a considerable degree of standardized design in order to reduce engineering design time. There are about 1.2 million engineers in the United States now employed in all sectors of the economy. In a technological future such as the NEE, it is reasonable to postulate that at least 2.0 million engineers will be needed. Some will be working for the vendors who manufacture the equipment that will go in the large plants, and some will be working in the end use area to design new kinds of vehicles, equipment, and processes. Many will be absorbed in other sectors of a booming economy. During the 25 years ahead, about 600,000 engineers will retire, so the universities will need to produce 1.4 million new engineers before 2000. The current graduation rate is about 40,000 per year and dropping, so that over 25 years, it looks like less than 1.0 million will graduate. This apparent shortfall could be overcome if more young people can be induced to choose engineering as a career. However, the numbers in the age group that will be entering the universities will dwindle beginning in 1976 and continue to decrease over most of the time period in question. See Fig. 10.2 and Table 10-2.

The construction, operation, and maintenance manpower required for the energy sector of the NEE grows to nearly 2.8 million people by the year 2000. There are currently shortages of pipefitters and other skilled craftsmen. If the wages and working conditions are attractive, some of these people can probably be lured from other sectors of the economy. Also, womanpower cannot be ignored; recently, some female pipefitters were hired to work at the Brown's Ferry Nuclear Plant in Alabama. Here again, there are not going to be as many young people as there have been. Sizable training programs will be needed.

The amount of steel and concrete required to build the facilities for the NEE are given in Fig. 10.3 and Table 10-3. Note that the bulk of the steel still goes into resource recovery, primarily fossil fuels extraction and delivery. Rather than a shortage of these basic commodities limiting industrial expansion, it appears likely that the items in the list below will be difficult to obtain:

Turbo-generator sets;

Reactor pressure vessels;

Heat exchangers;

Compressors;

Pumps and motors;

Transformers and switchgear;

Suitable sites;

Cooling water;

Draglines.

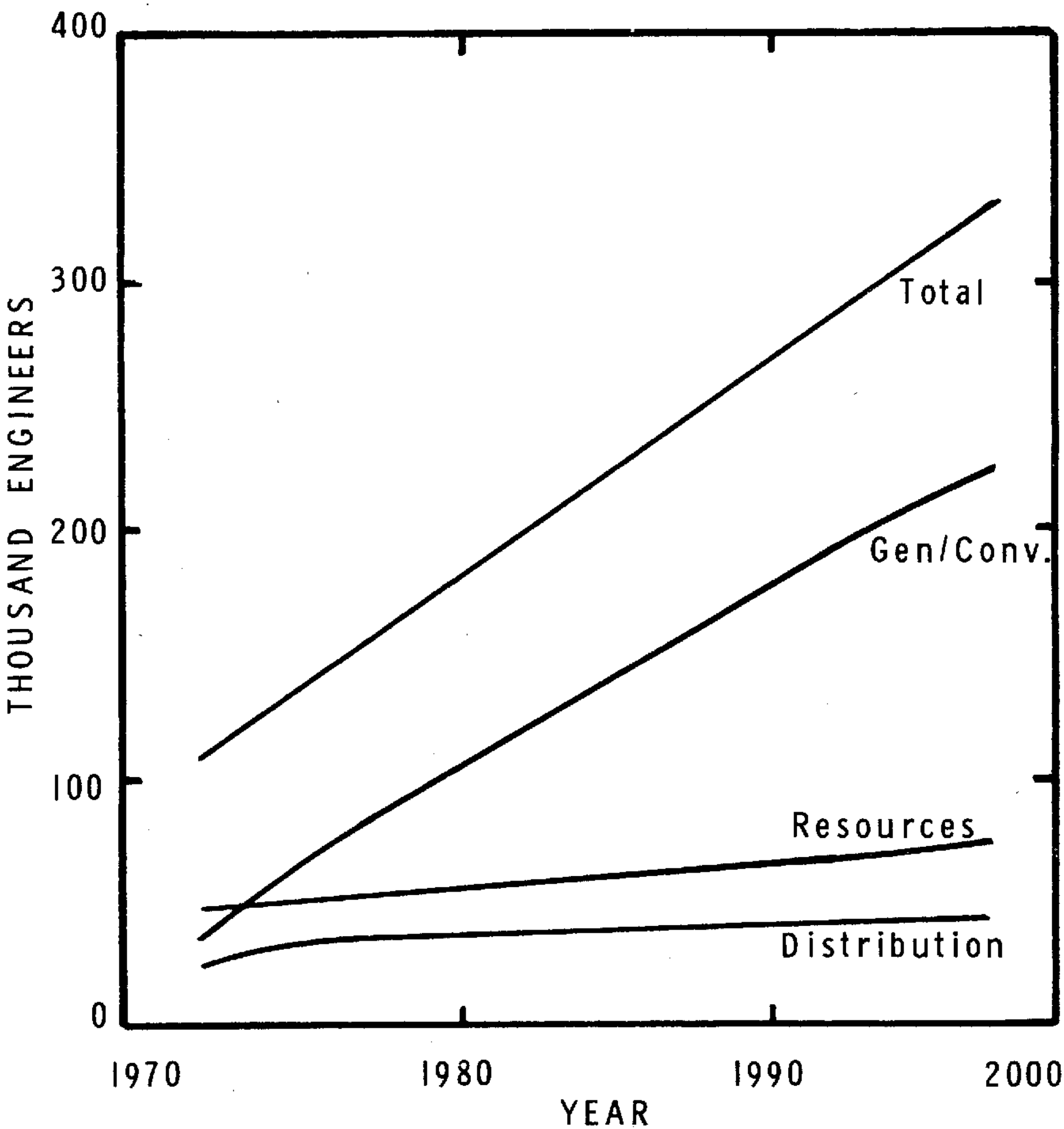

FIGURE 10-2 ENGINEERING MANPOWER REQUIRED
FOR THE NUCLEAR ELECTRIC ECONOMY

TABLE 10-2 MANPOWER REQUIREMENTS FOR NUCLEAR ELECTRIC ECONOMY (1000 PERSONS)

Period Ending	(Present) 1973		1980		1985		1990		1995		2000	
	Eng's.	Non-Eng.	Eng's.	Non-Eng.	Eng's.	Non-Eng.	Eng's.	Non-Eng.	Eng's.	Non-Eng.	Eng's.	Non-Eng.
Resources	46	580	48	610	53	670	57	730	63	820	71	920
Gen/Conv.	34	180	75	380	120	620	150	810	190	900	220	1000
Distribution	25	670	32	680	35	740	36	790	38	830	40	850
Totals	105	1430	155	1670	208	2030	243	2330	291	2550	331	2770

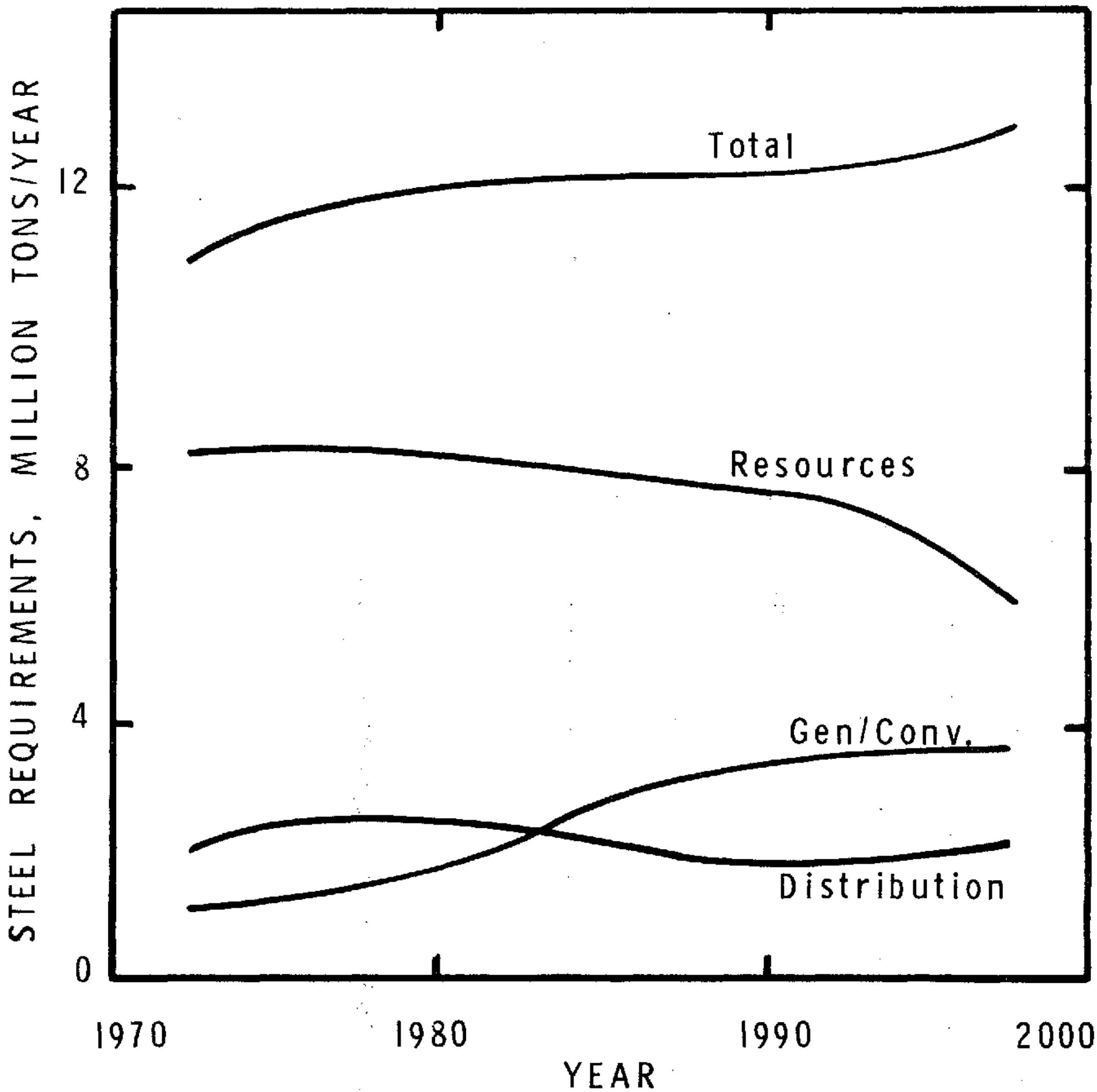

FIGURE 10-3 STEEL REQUIRED FOR THE NUCLEAR ELECTRIC ECONOMY

TABLE 10-3 STEEL AND CONCRETE REQUIREMENTS FOR NUCLEAR ELECTRIC ECONOMY

(STEEL IN MILLION TONS)[b], (CONCRETE IN MILLION YD^3)

Time Period	(Present)[a] 1973		1976-1980		1981-1985		1986-1990		1991-1995		1996-2000	
	Steel	Concr.	Steel	Concr.	Steel	Concr.	Steel	Concr.	Steel	Concr.	Steel	Concr.
Resources	41	15	41	39	40	36	38	37	37	36	29	27
Gen/Conv.	5	7	8	18	10	34	16	45	17	57	18	62
Distribution	10	-	12	-	12	-	9	-	9	-	10	-
Totals	56	22	61	57	62	70	63	82	63	93	67	89

a) Total for five years.

b) Steel requirements do not include steel in vendor supplied equipment.

The vendors who supply equipment for power plants, synthetic fuel plants, and other operations in the nuclear electric economy will have to grow with the scenario.

10-3 IMPACTS

An attempt is made to bring into focus the direct first order impacts of the NEE. These impacts are presented in Table 10-4 and Figure 10-4. The entries in Table 10-4 summarize what this task group sees as the most important impacts of this scenario. An enlarged Impacts Matrix incorporating more detail considerations is shown in Figure 10-4.

The columns of the enlarged impacts matrix are explained as follows: In columns for requirements, i.e, 'Need for newly-designed equipment', 'Equipment manufacturing capability', 'Skilled manpower', 'Water availability', 'Availability of capital', and 'Education' a minus sign (-) implies a sizable drain on available supplies. A double minus (--) indicates a very heavy drain.

In the 'energy efficiency' column, an attempt is made to address net energetics. A plus (+) means better than most other approaches; a minus (-) means net energetics is unattractive. 'Reliability' denotes availability of equipment on demand. A minus (-) sign indicates problems with reliability.

'Air pollution' includes particulates, SO_x, Kr^{85}, and any other undesirable airborne contaminants. 'Land use' connotes the dedication of land to a particular purpose; large tracts, or exclusive dedication for a long period rates a double minus.

In the 'Balance of payments' column, plus indicates likelihood of foreign currencies coming in, minus indicates U. S. money going abroad. Labor-intensive industries get a plus in the 'Full employment' column.

The assignment of relative rankings to the impacts of the actions for the NEE scenario is a subjective process. Figure 10-4 summarizes the judgement of the task group regarding first-order impacts. Obviously, the matrix could be expanded to include other activities and impacted sectors, and the ones that were chosen may not be the most important but were generally believed to be so by the group. A general discussion of how these activities cause specific impacts is given in Chapter 8, and will not be repeated here. Higher-order impacts were not addressed, but their significance is not to be discounted in a more complete technology assessment of the NEE than was atempted here.

Several specific impacts of the NEE are noteworthy. In the area of technological impacts, there is much need for newly-designed equipment; for example, automatic mining machinery, large 4000 hp slurry pumps for coal transport and electric cars. These endeavors will employ many engineers and perhaps spawn new industries.

DOING THIS ↓ / AFFECTS THIS →	NEED FOR NEWLY DESIGNED EQUIPMENT	EQUIPMENT MANUFACTURING CAPABILITY	ENERGY EFFICIENCY	RELIABILITY	SKILLED MANPOWER	WATER AVAILABILITY	WATER POLLUTION	AIR POLLUTION	NOISE POLLUTION	AESTHETICS	LAND USE	THERMAL POLLUTION	CLIMATIC CONDITIONS	ENVIRONMENTL RADIOACTIVITY	AVAILABILITY OF CAPITAL	INFLATION	BALANCE OF PAYMENTS	ENERGY PRICES	FULL EMPLOYMENT	NATIONAL SECURITY	FEDERAL REGULATIONS REQ'D.	STATES' RESPONSIBILITY	HEALTH & SAFETY	EDUCATION
PROSPECTING					-										-			?	+			?		-
CIVILIZING REMOTE AREAS	-	-	-		-	-	—	-		-					-	?	+	?	+	+	-	-		-
STRIP-MINING		-	+			—	—	-	-	—	—				-		+	+		+	-	-		
UNDERGROUND MINING	-	?		-	-	-	—	-		-	-				-		+	+	+	+	-	-	—	
DRILLING	-	-			-	-	-		-	-	-				-	+	+	+	+	+	-		-	
CLEANING COAL	—		—			—	-			-	-				-			-					?	
RESTORING LAND	-		-			-				+	+				-	?		-			—	-	+	
STORING GAS & OIL		-	-							-	-				-		+	?		+				
BURYING PIPELINES			?	-						+	-				—			-	+		-	-		
SLURRYING COAL	-	?	-			—	?		-						—		+							
IMPROVING INLAND WATERWAYS	-					?	-			-					—			?			+			
USING BARGES & TANKERS	-	-	+	?			—								-			+			-			
TRUCKING			-					-	-		-											-		
SHIPPING BY RAIL	-	-	+	?				?	-	-	-				-			+						
ACQUIRING LAND										?	·				-						—	-		
BORROWING MONEY															·	-		-	+		-			
MAKING SYNTHETIC FUELS	-	-	-	?	-	-	-	?		-	-	-			-		+	-	+	+			?	-
MANUFACTURING NUCLEAR FUEL			?	?	-									-	-		+		+	?	-		?	
BUILDING POWER PLANTS	-	?			—	-	?	-	-	-	-				—			?	+			-		
GENERATING ELECTRICITY		-	-	-	—	-		-		-	-	—	?	-	+				+		-	-	?	
HANDLING PLUTONIUM	-		-	—										—				-		-	-		-	-
USING COOLING TOWERS		-	-			+		-		-	-	+	?		-			-		-	-		-	
BUNCHING A NUCLEAR PARK	-	-	?	+	-	—	-	-		-	—	-	?		-			?			-	-		
DISPOSING WASTES	-		-	?	-	-	—	-		—	—			-	-			-			-	-		-
DECOMMISSIONING										-					-			-			-	-		
ERECTING TRANSMISSION LINES	-	-			-				-	—	-				—				+					
DRIVING ELECTRIC CARS	—		?					+	+						-									-
ELECTRIFYING RAILROADS	-	?	-	-	-			?							-				+		-			
USING HEAT PUMPS, ETC.	-	-			-										-				?					-

LEGEND:
'+' MEANS FAVORABLE IMPACT
'-' MEANS BAD IMPACT
'—' MEANS VERY BAD IMPACT
'?' INDICATES A FEELING THAT THERE IS SOMETHING THERE, BUT WE DON'T KNOW HOW TO EVALUATE IT
'·' MEANS ACTION IS ALSO AN IMPACT

FIGURE 10-4 EXPANDED IMPACTS MATRIX FOR NUCLEAR ELECTRIC ECONOMY

TABLE 10-4 COMPRESSED IMPACT MATRIX FOR NEE

Impacts / Activity	Technological	Environmental	Economic	Political/Social
Resource Extraction	New Equipment	Despoiling, Restoration	Many People	State Sovereignty
Transportation	Upgrading	Right-of-way	Considerable Capital	Private Property
Generation/ Conversion	Many Large Plants	Pollution	Huge Investment	Gov't. Regulations
End use	Electric cars, trains	Better than Now	Change to Electricity	Throwaway Lifestyle

The negative environmental impacts are numerous. Strip mining has been under heavy criticism and will probably be severely restricted by pending legislation (Strip mining problems are discussed in Chapters 8 and 9). Water pollution from mining and milling can degrade water quality. Building roadways, railways, waterways and 40,000 miles of transmission lines makes artificial boundaries that inhibit wildlife movement, and may also have a significant effect on humans and their institutions, by creating a 'wrong side of the tracks'. The climatic effects of operations on the scale of the NEE are largely unknown. It is known that cooling towers cause fog and icing in winter, but what would the effect be of a 30 GWe nuclear park evaporating 400,000 gallons per minute into the atmosphere? The control and disposal of high-level radioactive waste is a problem that must be resolved soon. Entering a nuclear future without an acceptable plan to dispose of the fission byproducts is procrastination at best. The effects of trace plutonium in the environment, and the possibility of nuclear weapons in irresponsible hands also loom as potentially severe impacts.

Land use and land planning will, at times, run counter to the wishes of private citizens and companies. Indeed, to own land is coming to mean that one merely has occupying rights for a few years. A comprehensive land-use policy is clearly called for to protect agricultural areas and wilderness. There appears to be opportunity to coordinate rights-of-way, select sites in advance of need, and plan for subsequent use after decommissioning. Considering what has happened in the rest of the world, it is possible that the entire U. S. electrification system may be nationalized.

Part of the impetus behind the NEE is an effort to balance payments. Exporting nuclear technology while decreasing oil imports will help. A full employment economy is envisioned with a large segment of the population working in an expanding industrial base. These people can be expected to exert a lot of leverage in the voting booths to further their cause. National security will remain a great concern for decision makers and will raise many questions: Is selling reactors overseas a threat to security? Is a nuclear park a very prominent target for a guided missile? Is an electric economy especially vulnerable to sabotage?

Looking beyond the year 2000, it appears that whatever the source, whether fusion, fission, fossil-fired generation, or central-station solar most of the energy will be distributed via electricity. There is a possibility that single dwelling solar energy or a hydrogen economy might evolve, but these become more unlikely in the face of huge investments in electrical transmission and utilization facilities.

There is some concern about how continued rapid growth of U. S. industry will affect the rest of the world, particularly the developing nations. It is true that the NEE makes less demands on the international petroleum markets than some of the other scenarios. However, we may become dependent on South African uranium. If U. S. affluence goads other countries into rapid nuclear growth, then the problems noted above may become global.

10-4 SCHEDULE/DECISION POINTS/RISKS

The scheduling of growth in the nuclear electric economy is mostly a matter of long-term anticipation. The need for reactors, enrichment facilities, rights-of-way, electric vehicles, etc., must be perceived and agreed upon ten years or so in advance. There are several key technical decision points implicit in the NEE. For example, three decisions will have to be made about breeder reactors. In about 1985, U-235 reserves and price effect on the cost of electricity should be assessed to see if building numerous breeder reactors is really necessary. It may be possible to stretch the uranium supply by using thorium in High Temperature Gas Reactors or the so-called 'Light Water Breeder'. In about the year 2000, the Breeder will have to be weighed in the balance against solar, geothermal, and fusion power to consider if it really is a viable option for the centuries ahead. Fission may have a headstart advantage going into that day of judgement.

Decisions will need to be made about the electric automobile. What kind(s) of batteries or other storage means should be used? When should the auto industry start tooling up to mass produce them, and how can they be induced to do this? Can the government play a useful role by specifying performance, safety, and recyclability features in the early design stages? If the railroads are electrified, there appears to be an opportunity to optimize roadbed configuration, routes, and train design. Most of the railroads in the country are now dilapidated and electrification would be a good time to revamp the rail system. The railroads might be nationalized in the U.S., as they are in other countries.

There is an opportunity to use the waste heat from power plants if suitable industries can be located nearby. By omitting the last stages of the turbine, the utilities could sell steam at, say, 300°F. Also the warm cooling water might be useful for space heating or raising crops in cool climates. Desalination is another possibility. Technology to accomplish these possibilities on a large scale needs more study, as do incentives for industry to do it.

There are many events that could prevent the nuclear electric economy from evolving. A few of these are mentioned below.

The demand for electricity may not grow nearly as much as the scenario prescribes. Conservation, availability of other fuels, and saturation effects may combine to produce a total electricity consumption in 2000 that is only double present levels, not five times as much [Salter-73].

Prolonged coal strikes may lead customers to conclude that however abundant coal is, it cannot be depended upon.

Fear of radiation may dominate the populace to the point where they refuse to allow further movement down the road to a nuclear society. Such fear could be exacerbated by accidental or malicious incidents.

The economic condition of the country may not be able to sustain a debt load as large as the NEE requires. Tight money and inflation seem to go hand in hand with this scenario. In the future, people may devalue the work ethic required to build something like the NEE; they may decide it just isn't worth the effort.

Finally, there may be wars or worldwide famines which will divert the nation's priorities from expanding its electrical base. U.S. citizens may have to learn to get by on what is available.

10-5 CONCLUDING REMARKS

The NEE scenario is an attempt to accommodate exponential growth. It proposes greatly expanded use of uranium and thorium to meet the projected needs. There is little doubt that such exponential growth accommodation would be possible if the nation could marshall its forces as it would when waging a war or responding to a great natural calamity. However, the will to do it in this case is not apparent; the desirability and necessity of such growth is questioned in some quarters. Already, construction plans being cancelled in the nuclear industry mean that the country will fall short of the NEE's goal of 130 GWe capacity by 1980.

There is some concern that growth, as expressed in the NEE, in such highly technological industries will do little to ameliorate the plight of the poor and uneducated. And there is a feeling that by embarking on such a path, the United States is somehow ignoring the rest of its goals and its relations with the rest of the world.

The NEE scenario, besides using nearly all of our currently known reserves of uranium, by 2000, makes heavy demands on other resources, expecially coal. The burgeoning growth of NEE appears to invite a boom and bust sequence, [Meadows-72]. It calls for electrification of the country, which in turn will require developing new technologies. Electric cars and trains, electric industrial processes, and efficient dependable heat pumps are largely in the conceptual design stages now. It may take decades to identify the problems of such devices, and correct the initial designs. Only then can the increased efficiency envisioned be realized.

There is much concern about what the NEE would do to the environment. Even under the newly enacted laws, coal mining is still a source of significant water pollution, ruined land, and health hazards. The radiological hazards, particularly those associated with accidental, or malicious incidents, are the source of considerable uneasiness, as is the knowledge that the Atomic Energy Commission still does not have an acceptable plan for ultimate disposal of high level radioactive wastes. The possibility of four times as many transmission lines as now exist, crisscrossing the countryside is not pleasant either.

Finally, the amount of government bureaucracy and decisions that would be necessary to sustain the NEE seem staggering. Financing, siting, rights-of-way, construction standards, emissions, regulated competition, and perhaps even forced allocation will be under increased federal purview in the NEE. The types of social/political impacts in such areas are included in the preceding chapters about FTFB and AFTF. In the case of the NEE however, government action would be directed toward increasing energy supply and changing end use modes to conform with the NEE pattern.

CHAPTER 11. COMPARISONS AND CONCLUSIONS

11-1 INTRODUCTION

The U.S. energy dilemma is complex and cannot be resolved in the pages of a report. The MEGASTAR group addressed this dilemma by attempting to assess the problems of energy growth. A methodology, combining elements of the systems approach and technology assessment, is used to obtain specific requirements and impacts of three paths for U.S. energy consumption through the year 2000. The paths are the Nuclear Electric Economy (NEE), the Ford Technical Fix Base (FTFB) case and an alternative to the FTFB energy consumption in the year 2000, defined as the Alternate to the Ford Technical Fix (AFTF). Reasons for selecting these scenarios as sample problems are discussed in Chapters 6 and 7.

The systems approach is a powerful technique for analyzing and displaying the role of energy in the context of U.S. society. Moreover, the method employed by the MEGASTAR group to assess the selected energy futures is suitable for other national problems of a technical nature [TERRASTAR-73]. These matters are discussed in Section 11-2.

The main purpose of this report is to present the information obtained from the MEGASTAR study and to show the value of the systems approach to delineate and display the energy dilemma, options for the future,and their consequences. Hopefully, this information and insight will be valuable to decision makers at all levels of government and industry and to citizens concerned about the U.S. energy dilemma. The study used the NEE, FTFB and AFTF scenarios to focus on energy systems, technologies and resources. These scenarios are directly compared in Sections 11-3 and 11-4. Factors judged by the group to be important for assessment of energy futures, independent of a particular scenario, are reviewed in Section 11-5. In Section 11-6, the MEGASTAR study is discussed in relation to other energy studies currently underway and specific recommendations are made for progress beyond MEGASTAR. A summary of the report is given in Section 11-7.

11-2 ROLE OF THE SYSTEMS APPROACH IN NATIONAL DECISION MAKING ON ENERGY

11-2-1 THE SYSTEMS APPROACH: A TOOL FOR ORGANIZING NATIONAL DEBATE

Energy as a Requirement

There is an energy dilemma. The statement of the nature, magnitude, and duration of the dilemma is complicated by the social and political context of technological issues. The heat of debate leads to overstatement of the relative importance of individual aspects of the problem and to obscuring the total problem. The systems approach, however, emphasizes the display and analysis of a problem in its entirety.

Energy supply and utilization is but one requirement among a number of interrelated requirements of a viable nation. Figure 11-1 is a diagram of the U.S. as a system. The important features are the information flows, constraints and feedback, and the identification of energy as only part of the total system. The diagram illustrates the point that statements such as "Energy is the key to the future" are simplistic regardless of the technical appeal of such notions. The tradeoff operations depend upon the character of the nation, a political entity. The constraints and criteria of the national system are constantly changing as priorities and goals change. The constraints and criteria embody the social, political, economic, technical, and cultural facets of society. The system feedback derives from individual perception of the nation. A good example of the functioning of the feedback process as a modifier of goals is described by Solomon [Solomon-74]. "The postwar U.S. economy placed its highest priorities on the pursuit of maximum growth in demand, minimum unemployment and the quest for ways to affect the distribution of income shares. At least until 1965, it did extremely well because of this emphasis. After 1965 we added two other items to the high priority list -- one was military and the other environmental. In the process other objectives were short-changed, notably price stability, the external value of the dollar, and the incentives for expanding our basic capacity to produce. The predictable results . . . were inflation, devaluation, and shortages. Clearly "it" can happen, even here. But eventually "it" doesn't need to keep happening, and it won't keep happening if the economy is allowed what it now most requires--at least a temporary reordering of its priorities." Thus, when the system is not operating in harmony with its criteria, changes are necessary and the feedback mechanism is a method for suggesting change. In the U.S. the people, through their representative form of government and the market, adopt or reject actions proposed to effect change.

In 1974 the nation turned part of its attention to the energy requirement because other elements of the nation are affected by the increased costs, the apparent scarcity of energy, and the recognition that energy planning decisions reach far into the future. The dilemma exists because, in systems language, planning of other national requirements has assumed that the historically readily available supplies of energy in convenient form at decreasing real prices would continue. For some years the needs of the energy system itself have been deemphasized. The present overemphasis is also wrong and Section 11-2-2 suggests an alternate approach.

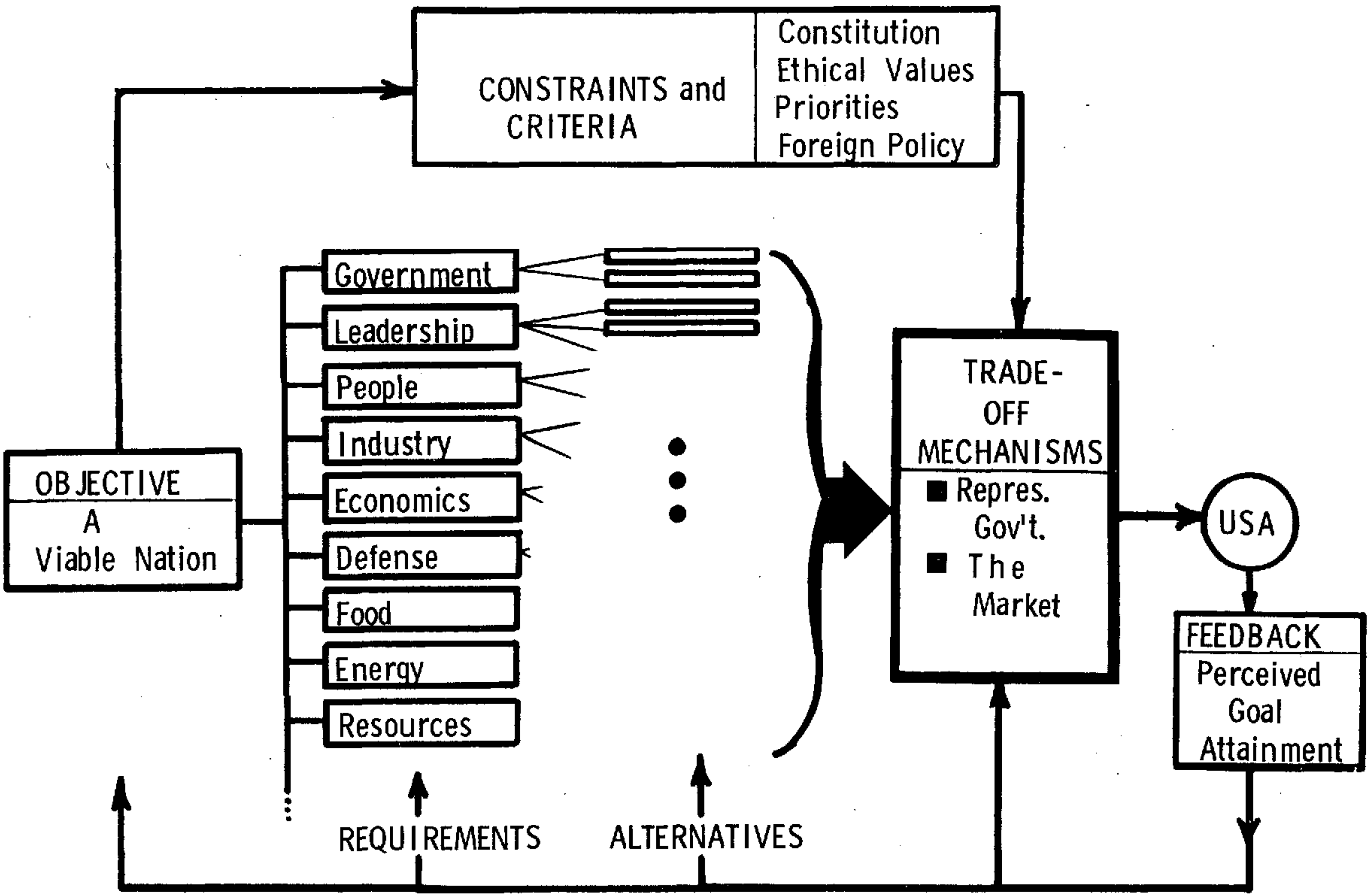

FIGURE 11-1 SYSTEMS APPROACH DISPLAY OF THE U.S. SHOWING THE NATIONAL ENERGY SUB SYSTEM AS A BASIC REQUIREMENT FOR A VIABLE NATION

Systems Approach to Energy Planning

The use of scenarios in planning energy development is a part of the systems approach in which each alternative for energy resources, power generation, conversion, and end use is examined as part of the subsystem embodied in the national system pictured in Figure 11-1. It should be emphasized that an energy scenario is visualized as a projection into the future on the basis of current data and not a rigid path to be followed year by year. The use of scenarios with the systems approach permits a projection of requirements and an assessment of the impacts of these requirements for various energy futures. This in turn allows the decision maker to choose an energy future that is most consistant with the constraints and criteria established by the nation. Energy planning is not static, but a process which should be reviewed periodically to take into account changing objectives and criteria. As an example of the lack of prior planning, the development of nuclear power systems begun in the 1950's had an assumption that nuclear reactors would be on-line in significant numbers in the late 1960's and would be the answer to the power problem. This assumption was overly optimistic and partly responsible for the lack of emphasis on research and development into other power systems. Now the nation is faced or will be faced with making decisions about fusion, solar energy, and other power systems. These decisions will affect the energy future 10 to 50 years from now. The constraints and criteria for these decisions must be realistic and not be dominated by either over-optimism nor pessimism.

There are a number of interrelated decisions that must be made in sequence if the potential of a future systems is to be realized. Each future system has a chain of decisions into the future with the initial point now or in the near future. Describing futures in scenarios gives the decision maker an opportunity to assess the consequences of various decisions in light of the constraints and criteria. Of course, ultimate decisions on future energy systems can only be made after the feasibility of all the concepts have been proven. An example of the critical nature of the decision process for an innocent sounding goal is the following. A goal that 90 percent of autos should have 25 mile-per-gallon fuel consumption by the year 2000 appears distant. This twenty-five year goal defines a 10-year production decision point (1985) if introduction of the new engine and car design is to occur between 1995 and 2000. This 10-year production decision point defines a 4-year design decision point to prepare for new designs and facilities. Thus, the twenty-five year goal requires decisions almost immediately.

The systems approach is valuable as a display mechanism for the national energy system and can be used to show the energy system's relationship to the national system which in turn is related to other political entities in the world community. All these political systems must in turn be related to the natural system of the planet. Thus the constraints and criteria of any political system consist of imposed constraints because of the existing environmental system and constraints imposed by interrelations with other political entities.

11-2-2 SYSTEMS MANAGEMENT

The energy system of the U.S. is large and functioning but lacks overall goals. There exists, and will continue to exist, fierce interfuel competition. In light of changing conditions in capital, import reliability, and resources, such competition can adversely affect many decisions with long-term consequences. The absence of planning leads to uncertainties in the energy system and can lead to unfair competition. This agrees with the National Commission on Materials Policy [NCMP-73] which observed

> "Long-term energy research and planning should be guided by national imperatives, and managed according to the most modern interdisciplinary techniques."

Programs such as the space program of the 1960's are examples of the effectiveness of systems management. Management under non-technical constraints and within a non-technical context will not be a straightforward extension of technical management, but can profit from the expertise of agencies such as NASA.

Systems design and engineering of an energy system for the future will begin in the time frame of 1975-1980. It will not be completed until several stages of reassessment of advanced technologies, such as the burner and breeder reactors, and speculative sources, such as fusion and solar-electric, have been finished. Moreover, many other national systems such as the automobile, mass transit and railroads are due for systems redesign within this time frame. It is important to manage preparations for such large-scale changes in a coordinated structure. Changes of the order envisioned can only be made over long intervals. Therefore the consequences must be well examined in the broadest context in order to minimize their undersirable aspects.

11-2-3 CRITIQUE OF THE STUDY

This section summarizes some of the areas of study and method which a longer and more thorough study should consider in more detail.

General Factors

The fluid present condition of the United States in terms of inflation, changeover of the administration, labor and world trade makes the scenario method difficult to justify. More analysis of the present should be included besides the present state of the energy system.

The knowledge of the potential for conscious disruption of the world energy system further limits the validity of a scenario method.

Access to detailed economic and social models would be beneficial to the study.

The evolution of the present out of the 1930's would be a good source of insights into dislocations and changing national priorities and goals.

The economics of the energy system is a subject at least as complex as the technological side.

The complete analysis of the industries making up the energy producing sector cannot really be separated from the rest of the nation's industrial base. This makes identification of bottlenecks quite difficult.

The complete treatment of the end uses of energy entails considerable detail of the whole economy.

A vital subject is the determination of the true driving forces of energy demand and price elasticity.

The Study

Iteration of the results of a study is beneficial but requires considerable additional time.

Impact statements herein are mostly first-order.

The systems approach emphasizes internal display and communication. These must be emphasized and well administered for success of a study of this type.

Many valuable results of a system study are contained in the synthesis and generalization growing out of tradeoff and iteration. The group members must participate in these activities fully.

In a group study of a multidiciplinary nature, contact with outside experts is a valuable data source.

11-3 SCENARIO-DEPENDENT FACTORS

This section makes manpower, material, and capital requirement comparisons among the three scenarios studied and summarized in Chapters 8, 9, and 10. It also contrasts the scenarios with respect to the roles that various fuels play and to the role that conservation plays.

11-3-1 MANPOWER REQUIREMENTS

The engineering manpower requirements for the three scenarios are shown in Figure 11-2. By the year 2000, the NEE path requires 2.8 time the engineers needed to support the FTFB path and 2.4 times the engineers to support the AFTF path. The AFTF requirement for engineers is always greater than that for FTFB for any year, reflecting the need for increased engineering effort in AFTF to overbuild the energy supply system in order to obtain zero energy growth at 2000. Both FTFB and AFTF require engineers to effect conservation measures.

In 1973, 105,000 engineers were employed in the energy sector and 1,200,000 engineers were in the U.S. workforce. Using the ratio (105,000/ 1,200,000 = 0.0875) and the projection that 2,000,000 engineers will be in the U.S. workforce at 2000, 175,000 engineers are projected to be available in the energy sector at 2000.

The manpower condition is a severe one for the NEE, which requires 331,000 engineers (17% of all engineers) at 2000. Either engineers must be attracted into the energy sector from the total engineering population or a substantiably larger number of engineering students must be graduated from engineering colleges than is anticipated. Engineering as a career must be made more attractive if the NEE is to be effected.

It appears that the projected engineering manpower figure of 175,000 (9% of all engineers) can support the engineering needs for FTFB and AFTF through the year 2000. The implication is that a surplus of engineers for these two scenarios is possible; however, the employment conditions for engineers between now and 2000 will probably keep the energy sector needs and supply in balance.

Non-engineering manpower requirements present a similar picture. Since the supplies of energy sector related skilled labor were not assessed they are not summarized here. There may be some supply problems in skilled labor, which should be assessed.

11-3-2 MATERIALS REQUIREMENTS

Figure 11-3 shows the steel requirements for the three scenarios. Generally, the AFTF and FTFB requirements are greater than those of NEE, reflecting the heavy reliance of the two scenarios upon gas and oil. Steel is required to carry out oil and gas exploration and development. The "kink" in the FTFB at 1990 comes from a drop in the need for gas and oil pipelines and tanker steel. This drop overrides the most significant steel requirement component, oil and gas exploration and development.

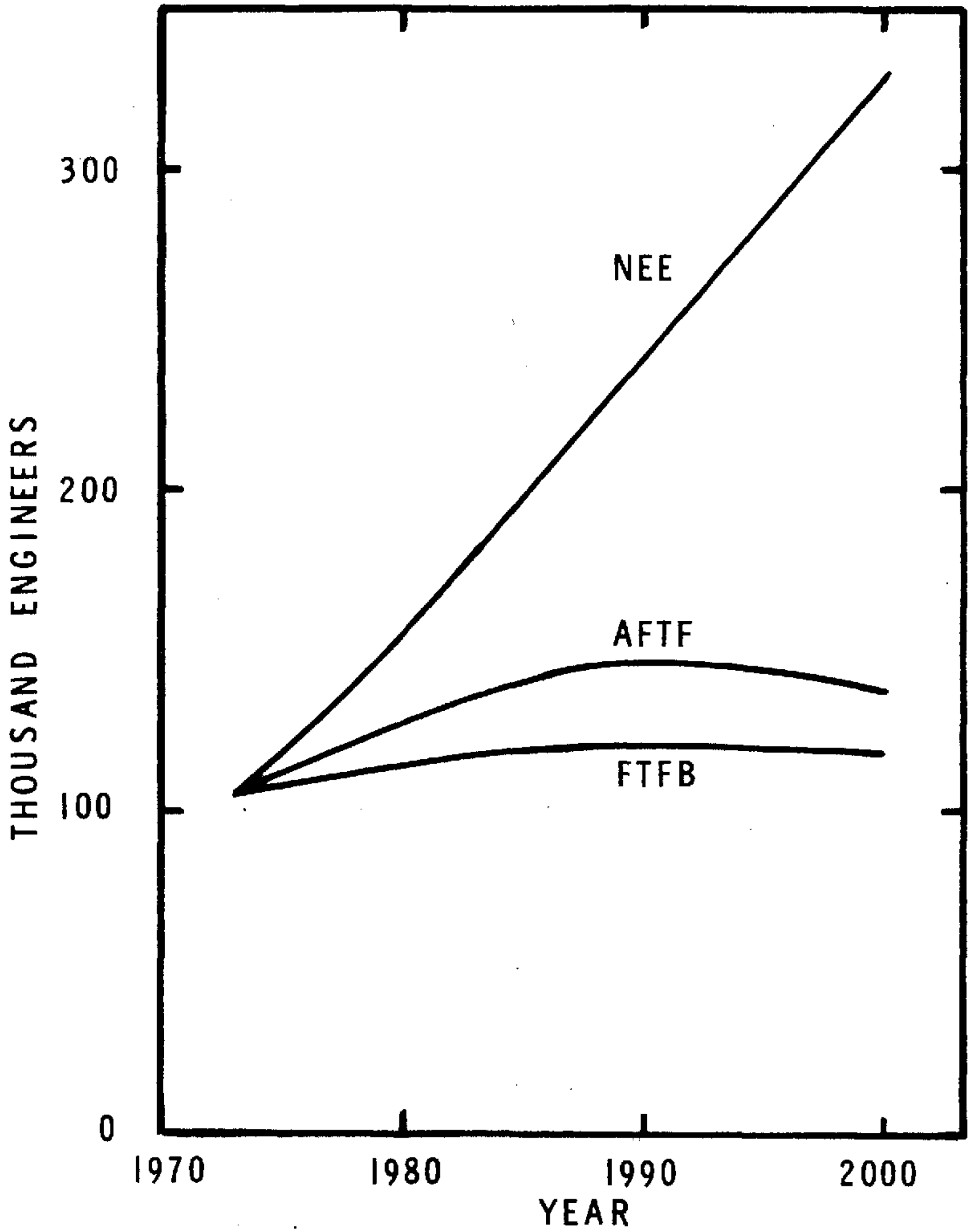

FIGURE 11-2 TOTAL ENGINEERING MANPOWER REQUIREMENTS FOR NEE, FTFB AND AFTF AS FUNCTION OF TIME

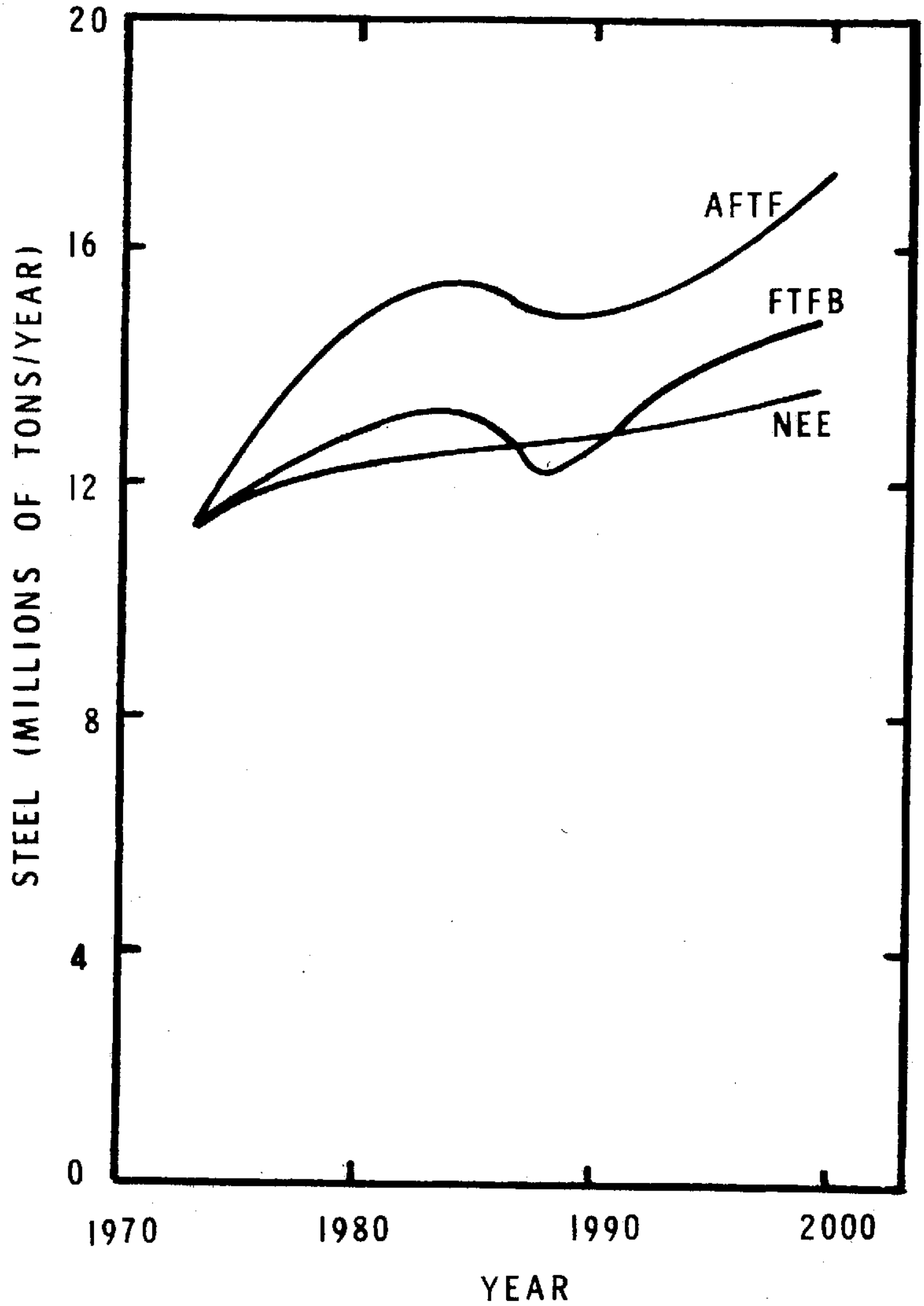

FIGURE 11-3 ADJUSTED TOTAL STEEL REQUIREMENTS FOR NEE, FTFB AND AFTF AS A FUNCTION OF TIME

About 10 percent of U.S. steel production is utilized by the energy sector. During 1973, 150.8 million tons of raw steel, including 111.4 million tons of mill products, were produced in the U.S. Projections to 1980 are 180 million tons of raw steel capacity and 133 million tons of mill products [Hein-74]. If a linear growth of the steel industry is assumed, 272 million tons of raw steel capacity and 201 million tons of mill products will result at 2000. If the energy industry uses the same share of mill products that it currently does, a supply of 20 million tons would be available - a value in excess of any demand for the scenario.

No problems are foreseen in this material area except for a possible steel mill product-mix imbalance. The study did not detail this problem.

11-3-3 CAPITAL REQUIREMENTS

The capital requirements for the three scenarios are shown in Figure 11-4. Because of its higher energy supply requirements, NEE is by far the most capital intensive of the three. AFTF requires more capital expenditure per year until 1997 than FTFB, reflecting the need to overbuild the energy supply system in order to obtain zero energy growth at 2000. The AFTF capital requirement does not go to zero at 2000 because replacement and energy supply charges are continuing. Gas and oil resource development also demands capital.

The capital available for investment in the U.S. is 18% of the GNP [Felix-72]. The 1973 U.S. GNP was 1025 billion dollars, resulting in 184.5 billion dollars of capital investment. The 1973 energy sector investment was 30 billion dollars, which meant 16% of investment capital was directed toward the energy sector. If the investment ratio and energy sector investment ratio of 0.18 and 0.16 are assumed constant to 2000, and the GNP is anticipated to be 2635 billion dollars [Felix-72], 76 billion dollars would be available for energy sector investment. This value is smaller than the projected NEE need for 87 billion dollars, but is clearly greater than the FTFB and AFTF capital needs. It appears that some concern for financing NEE exists <u>if</u> these ratios remain constant.

The FTFB and AFTF scenarios depend heavily on energy conservation. No attempt has been made to quantify the capital needs to effect conservation since it is viewed as an end use. The difference between capital available at 2000 and the needs of FTFB or AFTF must be sufficient to contain conservation capital demands, or else neither FTFB or AFTF will be economically viable. A detailed assessment of conservation costs should be made.

If FTFB of AFTF were followed, it is doubtful that 76 billion dollars would be available for investment. The reason is that historically capital investment is related to GNP and GNP is related to energy level, but under FTFB or AFTF the relation between economic growth and energy growth would be changed. The lower energy levels may imply lower available capital investment, but no detailed assessment of these interactions has been made. However, it still appears that FTFB and AFTF can be accomplished since the 1973 investment of 30 billion dollars should be able to grow to the required 40 billion dollars per year.

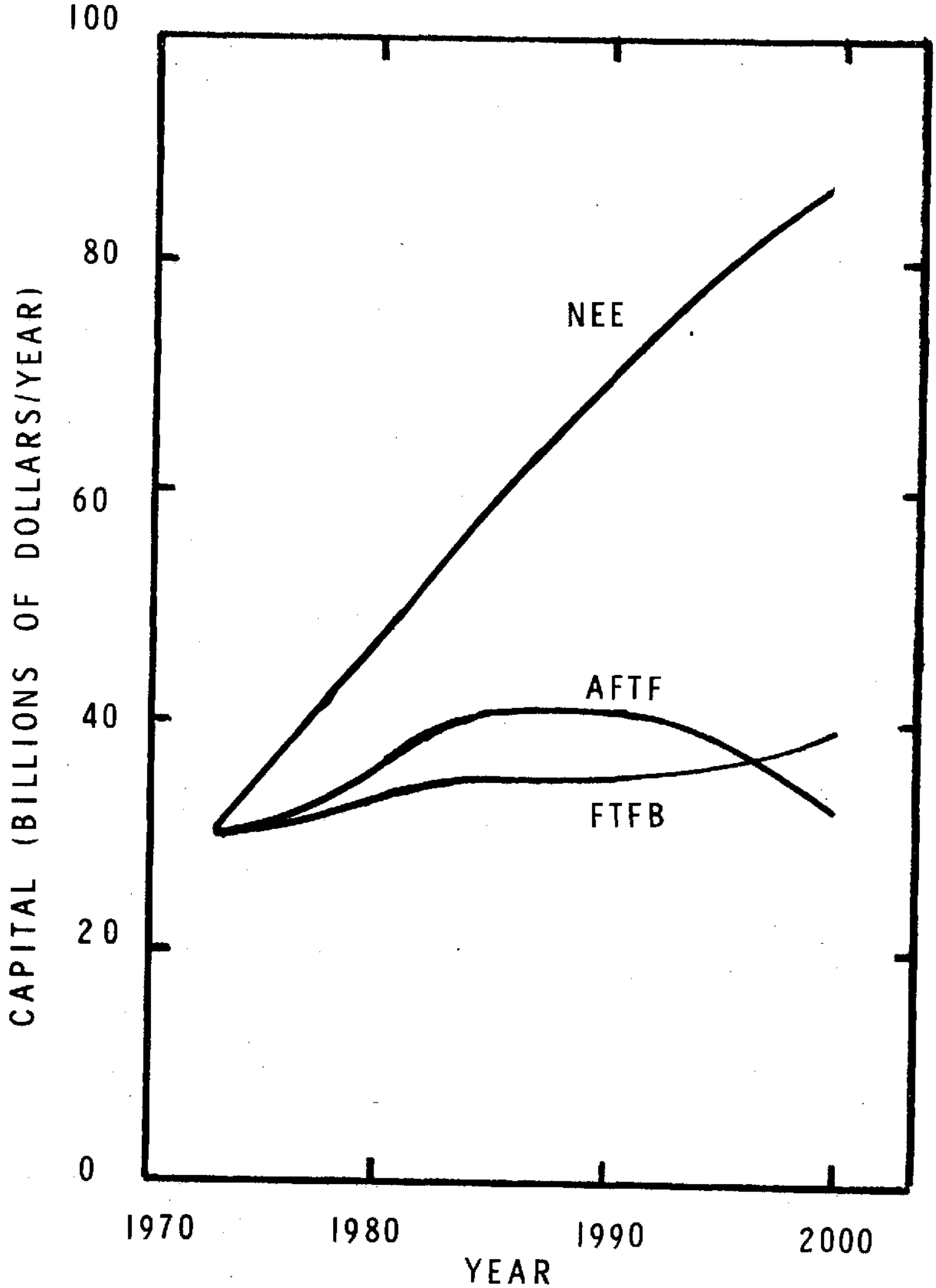

FIGURE 11-4 ADJUSTED TOTAL CAPITAL REQUIREMENTS FOR NEE, FTFB AND AFTF AS FUNCTION OF TIME

11-3-4 FUEL ROLES

All three scenarios call for increased use of the basic fuels. The percent increases over 1973 levels are shown in Table 11-1. The purpose of this section is to summarize the important assumptions necessary for the production of the fuels as outlined in Chapters 8, 9, and 10.

For all three scenarios, an assumption has been made that significant new domestic oil and gas reserves will be found including offshore reserves. The difficulties of actually finding these reserves are indicated below.

> In 1970, record additions to oil reserves were found totalling 74 Quads. Of this, 56 Quads were found on the north slope of Alaska at Prudhoe Bay. Excluding Alaska, approximately 18 Quads were added to reserves.
>
> In 1985-2000, 30 Quads must be added to reserves each year to satisfy the FTFB scenario.
>
> In 1975-1990, 33 Quads/year of oil reserves must be found to satisfy the AFTF scenario.
>
> In 1975-1985, 25 Quads/year of oil reserves must be found to satisfy the NEE scenario.
>
> Domestic oil reserves discoveries have been approximately 18 Quads/year in recent years and have been declining.

Clearly, the energy future of the United States is dependent on domestic oil discoveries if the United States is to avoid dependence on imports. Continued oil exploration incentives must be provided (see Section 11-5-2).

All three scenarios are heavily dependent on development and utilization of coal. Problems regarding this development have been discussed in Chapters 8, 9 and 10. The important thing to note is that, at this writing, coal development has received setbacks, and consequently the development of coal sufficient to meet any of the scenario requirements by 1980 is in doubt. Coal remains the largest fossil fuel reserve in the U.S., but for the short term coal will continue to provide a smaller share of fossil fuel energy than oil and gas. In the longer run, coal usage will depend on cost competition with nuclear electricity generation and upon future mining and air pollution technology and restrictions.

In all three scenarios, nuclear energy must provide an increasingly large segment of the U.S. energy requirements. Breeder reactor technology and commercialization are not required for the technical fix scenarios. The necessity for breeder commercialization for the NEE scenario depends on the future price of uranium fuels; but it is at present difficult to imagine PWR or BWR reactor construction in the 1990's based on present uranium resources. Nuclear power plants have an expected life of 40 years, and utilities will not build reactors without assured fuel supplies.

TABLE 11-1 INCREASES IN TOTAL FUEL USE FOR SCENARIOS
(PERCENT INCREASE COMPARED TO 1973 VALUES)

	Coal		Oil & Gas[a]		Nuclear	
Scenario	1985	2000	1985	2000	1985	2000
NEE	209%	500%	4%	4%	700%	4600%
FTFB	67%	127%	8%	24%	480%	820%
AFTF	92%	127%	33%	24%	250%	820%

a) Includes total Quads for oil and gas, regardless of source.

11-3-5 CONSERVATION

The energy savings attributed to "painless" conservation, i.e., improvements in end-use efficiency of energy, in the FTFB [Appendix E-2] and the AFTF were assumed to be the same. Some of the same kinds of savings were used in the NEE scenario. Table 6-2 compares the savings, in Quads, for the FTFB and the NEE scenarios. Some of the methods used for savings are the same; for example, use of insulation and heat pumps in buildings and homes, and transfer of hauling via trucks to rail, are present in all scenarios considered. On the other hand, FTFB and AFTF attributes a savings of 9.3 Quads to the use of 25 mi/gal cars by the year 2000, whereas NEE obtains 8 Quads of savings by converting 60 percent of the cars to electric. Obviously, the same kinds of actions that are necessary to implement change to 25 mi/gal cars [Section 8-2] would be necessary for electric cars. However, an additional consideration in the case of electric cars is the engineering development needed.

The NEE scenario projections for savings in the transportation area by 2000 also include 12 percent of auto transportation shifted to mass transit, 33 percent of truck freight and 10 percent of air passenger and freight traffic shifted to rail. These transfers are projected to save almost 4 times as many Quads as the FTFB in this area. This amount of energy savings is substantial since it is about the same number of Quads as is listed under the "Other" category in Table 6-2.

As can be seen in Table 6-2, 65 Quads of energy savings are projected by the FTFB scenario. During the course of this study, it became obvious that "painless" conservation is not necessarily painless. It is possible at a price, but the consequences of conservation actions should be thoroughly assessed. Most of the impacts of implementation of these energy-savings practices were found to be in the social/political area. In other words, implementation of these changes may require considerable government intervention. In the NEE scenario, the 40 Quads of savings attributed to conservation practices assume that not only will development of the requirements, such as suitable electric cars, trucks, buses, etc., take place, but also that these changes will be instituted. Once again the consequences of implementing such conservation practices must be carefully evaluated.

11-4 CRITIQUE OF FTFB, AFTF AND NEE SCENARIOS

11-4-1 FACTORS NOT CONSIDERED

The scenarios studied herein have assumed that U.S. society essentially continues as it is now in areas other than technology. Time beyond the year 2000 was not considered. Interactions outside the U.S. were not considered, with the exception of oil imports which were assumed to to be decreasing. Paths were energy-time curves, one for each source, and were constructed from smooth (no path or slope discontinuities) curves drawn through the present with its 4 percent slope, an intermediate 1985 point given by the scenario, and the future at 2000 with the slope defined by the scenario. Values at five year intervals were then interpolated. Section 4-3 points out that a more logical procedure would be to identify the energy consumers and portray energy as a requirement of the consumers' needs and activities. This, however, requires a broad statistical base and models of energy consumption. Such a procedure might identify areas of energy use in society where consumption is inadequate to meet human needs and point out directions for future policy.

A societal disruption can lead to a discontinuity in the path and would invalidate the above assumptions. War or famine would be examples of such disruptions. A decrease in oil prices by OPEC in response to U.S. resource development is another. Some observations that may indicate potential disruptions in society are:

> The world may be close to the population limits of growth and food and water shortages already exist in some areas (India and Africa).
>
> The disparity in consumption of the world's goods between the Third World and the developed nations is increasing.
>
> About 10 percent of the people of the U.S. live in poverty, i.e., in families of greater than two with less than $3000/ year income.
>
> Progress is continually needed on limiting nuclear weapons and controlling nuclear materials.
>
> Automation has the potential to achieve more leisure for society, or alternatively, to cause severe unemployment.

Once such a disruption does occur, review using a systems approach scheme would help judge whether the future need be modified, or the path adjusted to get back on an alternate path to the future.

11-4-2 QUESTIONABLE ASSUMPTIONS

Within the scenarios are implicit assumptions that are subject to debate. Chapter 6 discusses how both scenarios assume historical growth in energy demand, but that the FTFB uses efficiency of end use conservation to cut the historical energy growth rate in half. Historical growth for the war-time type economy of the 1960's has been extrapolated into peace-time. Inflation also compounds the problem. Such historical growth assumes inelasticity between price and demand and is mainly a consequence of cheap energy. The degree to which rising prices will reduce demand is unknown.

The NEE assumes electrification of society with a rate of nuclear growth that is very large. Already current AEC projections are below those of the NEE scenario for 1980 and 1985. The gas industry predicts gas production will rise if price deregulation occurs. The Prudhoe Bay field is expected to double domestic reserves if negotiations lead to a favorable decision for a gas pipeline through Canada. A huge distribution system of gas pipelines exist. Even if low estimates of gas resources prove correct the existence of this distribution system may slow down electrification. The need for water may require widespread desalination of saltwater. Nuclear reactor or solar heat to desalinate water, in conjunction with water dissociation to store and transport energy as hydrogen would allow the gas pipelines to continue to be used. A comparison shows that there are problems and advantages with either option.

Electrification	Gas
Huge energy loss as heat	Many sources (water, kelp, waste decomp., coal) yet to be fully exploited
Water must be available for cooling	Existing pipelines can be used
Visual pollution from distribution lines	Reserves are close to depletion
SO_x and fine particle pollution from coal	Feedstock for petrochemical industry.

The source mix path that characterizes each of the scenarios is limited to known source technologies. Flexibility to make use of more efficient end uses of energy is built in through what are called technical fixes. That same flexibility would be useful for sources. As time and research brings increased understanding of social and environmental costs, modifications will occur in the source mix. Ultimately fossil power and nuclear fission power are interim measures in progress to renewable resources. Path flexibility with target dates to bring in renewable source technologies would be desirable.

11-5 SCENARIO-INDEPENDENT FACTORS

Certain areas of concern are common to any discussion of the U.S. energy future. In this section, several are singled out as especially important in the judgment of the MEGASTAR group.

11-5-1 ELECTRIFICATION

A common feature of the three scenarios examined in this study is the trend toward increased use of electricity. This trend is not unrealistic since electrification has been increasing by 7 percent annually in recent years, double the overall energy growth rate. Indeed, the current uncertainty about domestic petroleum and natural gas reserves and incomplete development of processes to produce synthetic oil and gas from coal, makes electrification a logical goal. Nuclear fission and direct coal use are best suited for generation of electricity as well as fusion and central station solar. This indicates that electricity, however generated, will probably have a larger role in the future energy system. However, experience with a petroleum and natural gas-based economy has shown the problem of allowing one energy source to become dominant. Industry and transportation now require a growing supply of oil and gas with limited substitutability by other fuels. Moreover, dominance of oil and gas stunted the growth of coal and nuclear fission. Equipment, processes, and products designed to use electricity are not convertible to alternate power forms. Central station electrical generation and distribution networks would be powerful deterrents to alternate systems in an electric economy.

In addition, the future of nuclear fission is uncertain due to questions about the breeder reactor and the ultimate disposal of radioactive wastes. Nuclear fusion and central station solar power are not presently guaranteed alternatives to the breeder. In order for coal to become the dominant fuel measures are needed to prevent unacceptable environmental damage. Electrification with reactors and coal-fired plants will depend upon future advances in nuclear and coal utilization technology.

11-5-2 OIL AND GAS RESERVES

Considerable uncertainty exists regarding the undiscovered oil and gas which remains in the U.S. (see Chapter 1). Better knowledge of the oil and gas resource base would make decisions regarding energy planning and policy much easier. Determining the onshore resource base cannot be accomplished in a short period, but it appears that the offshore areas could be explored relatively quickly under Federal Government sponsorship. This should be seriously considered, <u>but</u> it could have adverse consequences. It would be advantageous to reduce the uncertainty regarding what is available: but, if considerable oil is offshore and is cheap to produce, it would be difficult to justify and encourage development of higher priced alternative fuels. Development of oil from shale would certainly be retarded, as well as other sources -- perhaps even coal. If low-price oil is available, difficult political decisions would be required to maintain sizeable oil reserves necessary to assure reliable supply.

11-5-3 TECHNICAL FIXES

The concept of technical fixes entails using technology to perform tasks more efficiently or in combinations to reduce consumption of primary fuels. Many applications are foreseen to offset the conversion losses inherent in electrification. Technical fixes include waste heat utilization, topping cycles, and heat pump applications -- both residential and industrial (see Appendix E).

Measures to eliminate waste should be encouraged in order to extend finite resources. In practice, however, the choice is basically between a higher initial cost due to the equipment for the technical fix or higher operating costs due to lower overall efficiency without the technical fix. Perceived cost to the purchaser will most likely continue to dictate the choice in the private sector. In industry discounted future costs are included in cost analyses.

It is not clear whether or not energy fuel savings alone will justify widespread applications of technical fixes. Subsidies are a means to favor the technical fix. If subsidies are provided however, this would imply a judgment that fuels are more valuable than their cost relative to that of the extra materials and productive resource needed to construct the technical fix.

11-5-4 CAPITAL PROBLEMS

The trend in segments of the energy industry toward an increasing share of the capital needs of the industry is currently of concern. The electric utilities, for example, are growing at an annual rate of 7 percent, but their capital needs are growing at 14 percent. This may reflect, in part, an attempt to expand the rate base. However, many utilities are experiencing a decrease in financial ratings with subsequent worsening of their financial condition. This problem must be addressed now to assure a strong utility industry.

The scenario-related capital problems of the energy industry have been discussed in Section 11-3 and under the assumptions stated there, the total capital requirements for the energy sector do not appear to be critical except possibly for the NEE. This assumes, however, that the energy industry will be as successful in the future in competing in the capital market as it has in the past as well as ignoring the capital problems of some sectors of the energy industry, e.g., the utilities.

11-5-5 ENVIRONMENTAL PROBLEMS

The energy industry must continue to provide U.S. energy needs without unacceptable environmental damage. If oil and gas use decreases while coal and nuclear fuels use increase, there will be a shift in areas of impact. Safeguards against oil well blowouts, pipeline ruptures, tanker accidents, and gas leaks will give way to more widespread concern over SO_x emissions, acid mine drainage, radioactive wastes, and nuclear accident potential. More electrification would result in more thermal pollution. However, 25 mpg cars and electric cars, if available in significant numbers, should decrease air pollution from mobile sources.

One of the costs of preventing unacceptable environmental damage is energy for powering pollution control equipment and to make up loses due to additional inefficiencies that may be caused by the operation of such equipment. For example, in al electrical generation plant, cooling towers require energy to operate and also decrease cycle efficiency by several percent. If the industry is able to meet environmental protection standards and to include the cost of the required equipment in the price of their product, no problems are foreseen. The problem is not energy vs. environment but in assuring that a sufficient part of the total energy produced is available for solving environmental problems.

11-5-6 MANPOWER TRAINING

If historical growth continues, shortages of engineering manpower will occur unless a larger percentage of the engineering population is involved in the energy sector or the total engineering population increases. Similarly, shortages of skilled craftsmen are anticipated. A potential solution to this problem is the establishment of training schools by industry itself in the construction areas. In the U.S. manpower is allocated by the market. Government could intervene to assure manpower supplies, but it would be a radical departure from present political philosophy.

11-5-7 CONSERVATION AS A RESOURCE

The scenarios treat conservation as if it were a resource in the sense that projected historical demand will be reduced by a certain amount of conservation. For example, suppose a heat pump is installed in place of electric resistance heating and air conditioning. The homeowner has the same comfort level, i.e., his standard of living does not decrease, but during each year of its operation the heat pump saves a certain amount of primary fuel by using less electricity than the former system. This savings of primary fuel is considered as a resource. Conservation by technical fix, is often referred to as "painless" (see Section 11-3-5). However, even though it may represent a net benefit to society it is often not totally "painless" to all the parties involved. For example, a manufacturer of oil furnaces probably would not find it "painless" if his business decreases due to the replacement of oil furnaces by heat pumps. Protecting the individual or group that is hurt by a social decision is a complex problem and one that has not been satisfactorily resolved in this country.

11-5-8 SOCIAL/POLITICAL CONSEQUENCES

In the examinations of the three scenarios presented in Chapters 8, 9, and 10, there was some discussion of Social/Political impacts of the individual scenarios. Independent of the scenarios examined, however, is the implied need for long-range planning. Although long range policies are developed and adhered to over many decades, there is no general acceptance in this country of long-range planning in which general guidelines are formulated for action, then reduced to the selection of an action option, which is then translated into action.

It would appear that scenario "builders" assume the presence of, or the establishment of, institutions that are both competent and ready to perform long range planning in an environment of broad social consensus. However, it is not apparent that institutions competent at long-range planning exist or are in the formation stage; nor can it be shown that a consensus exists that is supportive of a planning institution's function. The whole problem of the role of government in planning and in the carrying out of planning is one that is common to all of the scenarios and overshadows other social and political problems connected with energy. It basically hinges on the conflict between the good and rights of the individual vs. the good and rights of society and so goes far beyond the energy area. This group has no new insights on this problem, but does suggest that one of the things that is needed to help resolve this problem is a careful and thorough assessment of the costs and benefits that would accompany an expanded governmental role in the planning process.

11-6 ENERGY PERSPECTIVES

11-6-1 PRESENT ENERGY POLICY RESEARCH

There are presently two other major studies, not yet completed (Aug. 74), that complement this one. These are the Final Report of the Ford Foundation Energy Policy Project and the Project Independence Blueprint. Both of these studies are concerned with the development of a national energy policy.

The Preliminary Report of the Ford Foundation [Ford-74] has been discussed in Chapters 5, 6, and 7. The final report, called The Energy Report, will be published in December, 1974. It is the culmination of four years of effort to analyze the energy problems that face the world today and especially the U.S. The contents of the report have been released and are:

1. Looking Forward
2. Energy and Your Life
3. Energy, Economic Growth and Jobs
4. U.S. Energy Policy in the World Context
5. Energy and Environment
6. Consumer Safeguards
7. The Electric Utilities
8. Protecting the Public Trust
9. Energy Research and Development
10. Energy, Government and the Citizen
11. Historical Growth Scenario
12. The Technical Fix Scenario
13. The Zero Energy Growth Scenario
14. Conclusions

Advanced reports [Saulter-74] indicate that the final conclusion of the report will be that the most desirable scenario is the one which achieves zero energy growth by the year 2000. Unfortunately, there are no details available and, therefore, it is impossible to make any comparisons with the Preliminary Ford Report or with the results of this report. In the Preliminary Report [Ford-74]

zero energy growth occurs when total consumption reaches 100 Quads. If this level is retained in the Final Report, then it will complement the two cases considered in this report i.e. FTFB - 120 Quads and NEE - 200 Quads. Consequently, the 100 Quad level was not analyzed in this report. The Ford Final Report and this report should cover the major energy options open to the United States and hopefully will provide the information necessary for a major debate on a national energy policy.

Project Independence Blueprint is a study by the Federal Government of the U.S. energy situation which grew out of a 1973 presidential request for an energy policy that would eliminate U.S. dependence on imported oil. Since then the objective has been expanded to try to develop a national energy policy and to allow a small amount of oil imports. The study is being conducted by personnel from the Departments of Commerce, Labor, and Transportation, the Treasury, the Environmental Protection Agency, and the Federal Energy Administration. The study organization is shown in matrix form in Figure 11-5. There are nine source groups each of which is concerned with a particular fuel and six cross-cut groups each of which is concerned with a requirement such as manpower for all fuels. The results of these groups will be used as input for a complex, linear programming computer model. The model will attempt to balance energy supply and demand consistent with limitations of price, timing, manpower, capital, etc. The model will then be used to simulate various courses of action open to the U.S. in the energy area. The results of these simulations will be analyzed by EPA for environmental impacts. There is presently no comparable analysis planned for social and political impacts. The final result of this process will be recommendations for the President on the elements of a national energy policy. The final report is planned to be ready on November 1, 1974.

11-6-2 UNRESOLVED ENERGY PROBLEMS

In the course of this study, additional problems associated with energy were identified, but were judged to be outside the scope of the MEGASTAR report. An identification and discussion of several of these follows.

Energy Market and Government Intervention

The market system as it exists in the United States cannot be characterized as a purely competitive system. The energy market is no exception to this because of the oil oligopoly and regulated utilities, both gas and electric. Price fixing, by means of public service commission rate structures, and administered prices, that are common in the oil industry, are not features of a competitive market.

The market system, as it has traditionally existed in the U.S., is also not a full social cost market. The price that consumers pay does not often reflect the cost of polluting air, land, and water. A full social cost market system is unlikely to evolve in the U.S. without government intervention in the market or an unprecedented demand by citizens on industry to factor in social costs. In either case the result would be further movement away from a pure competitive market.

Cross-Cut Groups / Fuel Groups	Manpower	Finance	Water	Materials, equipment, construction	Environment	Transportation
Oil						
Natural Gas						
Nuclear						
Coal						
Oil Shale						
Synthetic Fuels						
Geothermal						
Solar						
Energy Related Facilities						

FIGURE 11-5 AREAS OF RESPONSIBILITY FOR PROJECT INDEPENDENCE TASK GROUPS

Government intervention in the market is nothing new; the oldest such intervention is the import duty, which provided some degree of protection for fledgling industry as well as revenue for the government. In the energy area, government intervention has also influenced the market; oil import quotas, which protected domestic producers from competition with cheap foreign oil, are an excellent example of intervention in the energy market place. There is some disagreement as to how much influence the Federal Government should exert in the energy market. However, as is pointed out above and in Section 1-2-3, the government is already involved and even a decision to withdraw its influence from the market would have significant consequences.

If a Federal energy policy is formulated, it is certain that it will guide government action with respect to the energy market. It is sometimes asserted that the government could not influence the energy market to the degree necessary without exercising unacceptable dictatorial control. However, a careful examination of some of the normal options open to government reveals many possible choices which are acceptable and reasonable; some of these options are already being exercised. Table 11-2 illustrates some of the options and their potential impact on energy production and consumption. Some of the options will be discussed briefly to illustrate them and their potential or present impacts.

Tax policies have far-reaching possibilities to influence production and consumption. For example, the oil depletion allowance has in the past, and to some extent in the present, lowered oil prices slightly. In general the tax break to the oil industry means that full costs are not passed on to consumers by way of prices. Lower prices in turn tend to stimulate demand. Direct taxes on the retail seller of a product, such as gasoline, can be used to depress demand by effectively raising prices. The oil depletion allowance is intended to promote exploration for resources, and it probably does stimulate wildcatting by independents. If the depletion allowance is discontinued there may be some need to replace its stimulus for wildcatting or the independents may be driven out of business leaving exploration to the major oil companies, thus reinforcing the present oligopoly.

Import controls (e.g., import quotas for oil) are another means of government intervention. These controls have been used in the past to protect U.S. oil producers from foreign competition. They could also be used in the future to protect domestic oil and/or domestic synthetic fuel industries from being undercut by low-priced foreign oil. Import controls, however, can result in retaliatory measures by other countries and such contols should be used with caution.

Government action in the market is not new and the options of taxes and import controls are tried and effective measures of influencing the market. However, there are other measures that can also influence the energy market that are essentially untried. Energy performance standards are an example of an untried intervention. Energy performance standards,

TABLE 11-2 FEDERAL GOVERNMENT POLICY OPTIONS THAT IMPACT ENERGY PRODUCTION AND CONSUMPTION

Effect on:	Production					Consumption			
Policy Area	Oil and Gas	Coal	Nuclear	Imports	Other a	Residential	Commercial	Transportation	Industrial
Taxation	X	X	X	X	X	X	X	X	X
Price Controls	X	X	X	X	X	X	X	X	X
Import Controls	X			X				X	
Energy Performance Standards						X	X	X	X
Environmental Regulation	X	X	X	X	X	X	X	X	X
Land Use Regulation	X	X	X						
Research and Development Support	X	X	X	X	X			X	
Government Stockpiling	X	X	X	X					
Government Subsidy of Industry	X	X	X		X				
Leasing Federal Resource Land	X	X	X		X				
Allocation of Scarce Fuels						X	X	X	X
Mandatory Restriction of Energy Use						X	X	X	X
Control of Utilities						X	X		X

X = direct, definable effect

a) Geothermal, Oil Shale, and Solar

that require energy performance information or require licensing of products would be new to the energy market, (although not necessarily a new option for government, e.g., FDA pharmaceutical and EPA emission standards).

Past government intervention in the energy market has been a fact-of-life for the energy industry, particularly in production, and to a lesser extent in consumption. However, in looking to the future one can ask, what will be the role of government in the energy market? This study has not revealed a precise answer to this question, but it is apparent that if one of the proposed scenarios is followed that the government's role will be expanding. The demand for a Federal energy policy is, in part, a demand for an expanded governmental role.

The expanded role of government will most likely intrude on the consumption of energy. In the past, government policies encouraged both a high level of production and consumption of energy. In the future, government policies will likely encourage the continued production of energy, but at the same time attempt to discourage consumption of energy. A gradual, but intense application of both tried and untried action options can be pursued in an effort to reduce growth in energy consumption.

These interventions may be indirect (e.g., encourage high prices to reduce consumption) or they may be direct (e.g., energy performance standards or incentives to consumers to use energy efficient devices). In either case these actions of government would be a reversal of past policies or postures.

These interventions in the energy market will flow from the realization by policy-makers that present energy resources are indeed finite. The option of greatly increased production becomes somewhat futile and conservation and curtailed consumption become more attractive policy options.

Comments on Zero Energy Growth

The finiteness of the earth's resource base, the finite capacity of the world for absorbing environmental damages, the limited share of the presently available energy now held by less developed countries, the eventual saturation of per capita demand--all these have been advanced by the Energy Policy Project [Ford-74] as reasons for ZEG. Related reasons for ultimately adopting ZEG as national energy policy are increasing competition for land and water between energy uses and other uses, such as food production, and possible decreased industrial demand for energy due to shortages or recycling of raw materials. ZEG may for some of these reasons eventually be adopted out of necessity or society may voluntarily choose to institute it sooner.

One factor affecting this decision is social constraint on the use of certain resources. There are well-known arguments against use of most resources, especially coal, uranium, and oil for energy generation. As time passes some of these arguments may produce social consensus that proscribes such use. Such social proscription (and mandating) of energy activities is one avenue for implementation of zero energy growth.

Another factor is economic: there are increasing tendencies to include more of the social costs of producing and using energy into the price of energy. Such increased energy prices that result in decreased use are another way to reduce demand.

A third factor is change in social values. An ethic is surfacing among some segments of society that calls for wise use of the earth's resources; some people do not think that society now has the knowledge needed to make wise choices. They conclude that further resource development should be delayed.

A fourth factor is society's perception of its own ability to absorb the short-term dislocations and long-term social changes that ZEG would entail.

Further discussion of ZEG is included in Appendix 9-3-4. That discussion and the comments above illustrate the fundamental role that social choices play in the determination of energy policy. It also points out that considering only the technical aspects of energy is unrealistic.

The Drivers of Demand

Two reasons can be cited for increasing per capita demand for energy:

(1) Rising expectations. People strive to improve their standard of living-bigger homes, more cars, more energy-intensive manufactured things-and expect to acquire these sooner than their parents did. However, such expectations are tempered by shortage of disposable income. The growth of multiple-family apartments at the expense of single-family homes in recent years is a case in point. Furthermore, there is a saturation level for air conditioning, driving, and lighting beyond which further energy use seems unnecessary.

(2) Technology changes. Energy to run sulfur removal devices, cooling tower fans, synthetic fuel plants, and industrial automation has to come from somewhere. However, new process designs will strive to minimize energy consumption [Brown-74]. Furthermore, growth in demand for the products of automated industry is governed, ultimately, by consumer demand, which may be constrained by available funds and saturation.

Total demand is also driven by population. Although the U.S. has essentially reached a zero population growth rate [U.S. Census-72] there will still be a projected increase by the year 2000 of 40-50 million people or 20 to 25 percent of the present population. Consequently, services and , in particular, energy supplies will have to grow to provide for this increase in population.

National Energy Policy

One of the things that has become apparent to this group and to others is the need for a national energy policy. At present a mixture of regulations and directives are evolving out of the activities of legislative and regulatory bodies, but they are fragmented and often contradictory. In addition, many of the problems already discussed in this report concerning the production and use of energy must be resolved in the near future if the U.S. is to avoid

more energy "crises" such as occurred with the Arab oil embargo. For reasons also discussed elsewhere in this report failure to act in the near future will also have consequences, most of which appear to be unpleasant, such as balance-of-payment problems. Failure to act will mean that energy will become another nagging, unsolved problem facing our society.

It is , however, easier to see the need for a national energy policy than to recommend what such a policy should entail. Rather than make specific policy recommendations it is the point of view of this group that a national debate on an energy policy is imperative. It is hoped that the information on energy futures contained in this report will be of value in such a debate. If such a debate is to proceed rationally there is a need to diseminate as widely as possible the results of this report and all other investigations concerning energy policy since fundamentally the choice of a policy must be made by the people and their governmental representatives.

The Relationship of the U.S. to the Rest of the World

Although the focus of this report has been on the U.S. energy system, it is recongized that the U.S., in energy as in other areas, does not exist alone. The only external interaction that was explicitly taken into account in this report was the importation of oil and gas. One of the important problems with long-term, international, social and political implications that was not considered in this report is the problem of the world-wide distribution of energy supplies. Energy consumption around the world is as follows [de Castro-71]:

U.S.A.	West Europe	U.S.S.R.	*China	*Asia	East Europe	Japan
35%	25%	14%	4%	4%	4%	3.5%

*Africa	Australia	Canada	*Latin and S. America	Industrial Countries	*Third World
2%	1.3%	2.2%	5%	85%	15%

The third world contains 80 percent of world population and the U.S. 6 percent. About 216 Quads were consumed in the whole world in 1972 [Felix-72]. How energy might be distributed more equitably remains an issue. Some reasons for the continued frustration of the developing countries have been reviewed by de Castro. The same reference offers a timetable of suggested systems approach studies, and U.N. recommendations among which are a financial flow of 1 percent GNP from developed to developing nations, 5 percent of R and D on problems related to third world needs, and .05 percent of R and D for grants directly to third world countries for R and D within the developing nations. Felix presents a GNP growth model for each country that slowly decreases the disparity. The functional relationship between GNP and energy consumption is unclear. France and Sweden have nearly one-half the energy/GNP ratio that the U.S. does [Simmons-74].

A rough estimate of world energy supply and demand is as follows. A total of 54×10^6 Quads of solar energy strikes the earth each year. About 30 percent of this energy is reflected from the atmosphere; 7 percent strikes the surface and the rest is absorbed by the atmosphere. Of the 7 percent that incidents the earth's surface, 7.2×10^4 Quads strikes land surface. If 10 percent is assumed convertible to useful energy [Hottel-71] there is a steady state limit of 7200 Quads of solar energy per year. This compares with fixed reserves of approximately 200,000 Quads of coal, 200,000 of uranium, 9,000 each of oil and gas, and 7 trillion Quads of deuterium. These are U.S.G.S. estimates of matter in place [Eister-74]. Twice the present world population consuming energy at present U.S. per capita rates yields a guessed-at steady state consumption of 2400 Quads per year. Once the world consumes at this rate, oil and gas would last 10 years assuming all could be extracted. Assuming half the coal might be removed and half the uranium, another 100 years would be allowed. The breeder will extend this, but ultimately fusion, or solar (with all its variation; e.g., ocean thermal gradients, photosynthesis, wind, etc.), will be required.

It is unlikely that the rest of the world will continue to tolerate the wide differences in per capita energy consumption that now exist. This will mean increased competition and therefore, prices for international energy resources and the materials necessary to utilize those resources, such as nickel. The changes which would accompany any such shifts in per capita energy consumption have a considerable potential for the generation of international problems, e.g., the Arab oil embargo. This is a problem which requires careful examination in the near future.

Technology Utilization

A systems approach is only as good as the means available for coordination of communication since all parts of the system must be aware of the status of the other parts. The vehicle for this communication could be a national program of technology transfer. Programs of this type exist in the Patent Office, NASA's Technology Utilization program, and the NSF/RANN program. If energy planning is to make use of systems management and design then many colateral technological areas must be addressed simultaneously.

Several broad areas of necessary future technology development have been identified by the MEGASTAR group. These areas are enumerated as examples of technology which will be basic to energy systems planning. It is felt that pricing and other incentives will probably act to speed adoption of new technology in these areas.

Low grade Heat Both scenarios examined indicate great potential for conserving energy by investing in equipment to utilize more of the available energy in a fuel or to make up for conversion losses in electrical generation. The technology of heat transfer, heat pumps, heat transport, and insulation are examples.

Materials Material shortages will require the development of materials substitutes. Development of novel and special purpose materials has advanced in recent years and will need to continue if energy goals are to be met.

Fabrication New fabrication techniques will be necessary to handle new materials and to provide increased energy efficiency in industrial processes.

Control Systems Many opportunities for improving control systems should emerge. Sophistication of control systems must increase because of the increasing complexity of tasks. An example would be the control problems in a dual solar-fossil home. Every aspect of control systems present opportunities for innovation: sensors, transducers, signal and control paths, decision electronics, telemetry, alarms, recorders, and actuators and indicators.

Technology for Conservation The need for increased efficiency in energy use and new technology, e.g., electric cars, should produce a new growth industry to supply these requirements. Such an industry should also have a good potential for technology export to the rest of the world.

11-7 SUMMARY

The purpose of this report is to describe the results of a systems study of the U.S. energy dilemma by the MEGASTAR group. The objective of the study was to produce a method of energy system assessment and to apply it to several examples of potential U.S. energy futures. The methodology was based on a combination of the systems approach and technology assessment modified to apply to the U.S. energy system. A discussion of the methodology is given in Chapters 2, 3, and 4.

In order to test the methodology it was applied to energy futures at the year 2000 proposed by the Ford Foundation Energy Policy Project [Ford-74] and by the Westinghouse Corporation [Ross-74]. The future proposed in the Preliminary Report of the Energy Policy Project emphasizes conservation by "technical fix," i.e., more efficient end use of energy, and a reduction in the energy growth rate to 1.7%. Its primary fuel source is still oil and gas. The future proposed by Westinghouse is called the Nuclear Electric Economy and relies upon a substantial increase in the use of coal and about fifty times the present production of energy by nuclear fission. It is also characterized by a shift to electricity as an energy form and a continuation of the historical energy growth rate of 4%.

Once these future points were chosen several alternate paths from the present to those two points were considered. It was decided that three of those paths would be analyzed further. These were the original paths associated with the two scenarios and an alternate path to the Ford Report future point developed by the MEGASTAR group. This path was characterized by an initial growth rate higher than the Ford Report path, but with a transition to zero energy growth at the year 2000. The details of these paths and future points are found in Chapters 5,6 and 7.

After the paths were identified the next step was to determine the manpower, materials and capital necessary to realize each path. Then the technical, economic, environmental and social/political impacts of those requirements were assessed for each path. The results of this process are given in Chapters 8. 9, and 10 and consist of the requirements and impacts that must be met to achieve each path.

It is hoped that this information about the consequences of some of the possible energy futures open to the U.S. will be useful to those in all areas of society, government, industry and private citizens, who will have to decide the future course of U.S. Energy Policy.

Although it was the intention of this study to provide decision makers with better information for decision making and not to make recommendations there are several points that have become apparent during this study that the group feels are worth emphasizing. The first is that the systems approach has been found to be a powerful tool for analyzing the U.S. energy system and is probably the only way that a comprehensive study of such a complex system can be successfully made. The second point is the need for further study in the energy policy area. In addition to the Ford Foundation Energy Policy Project Study the only other major energy policy study presently under way is Project Independence Blueprint (see Section 11-6-1). This group urges others to investigate additional alternative U.S. energy futures so that as much information as possible regarding various energy policy options is available so better decisions can be make in this area. The final point is a strong feeling of the group of the need for an immediate, national debate on the content of a U.S. energy policy. There has never been a comprehensive national energy policy comparable to U.S. Foreign Policy or Defense Policy. The sense of urgency is derived from the analysis of this study which indicates that in order to plan rationally for a future at the year 2000 many socially far-reaching decisions must be made in the next few years. To postpone the adoption of a national energy policy is to invite continued energy "crises" and crisis management. Both the final Energy Policy Project Report and the results of Project Independence Blueprint are planned to be available by the end of 1974. It is hoped that the Congress in its next session and the Administration will present all the available information on a national energy policy to the American People to begin an informed national dialogue which will result in the adoption of a U.S. energy policy.

APPENDIX A. ABBREVIATIONS

AC	- Alternating Current
AEC	- U.S. Atomic Energy Commission
AFTF	- Ford Technical Fix, Alternate Path Scenario
AGA	- American Gas Association
AUI	- Associated Universities, Inc.
BBL	- Barrel, petroleum measure, 42 gallons
BCOE	- Barrels of Crude Oil Equivalent
BT	- Billion Tons
BTU	- British Thermal Unit
CANDU	- Canadian Deuterium - Uranium Reactor
CEQ	- Council on Environmental Quality
CIEP	- Committee for International Environmental Programs
CMB	- Chase Manhattan Bank
COG	- Coal - Oil - Gas
DC	- Direct Current
DOC	- Department of Commerce
DOI	- Department of Interior
DWT	- Dead Weight Tonnage
EFG	- Edge-defined Film-fed Growth
EPA	- U.S. Environmental Protection Agency
EPO	- Energy Policy Office
EPP	- Energy Policy Project (Ford Foundation)
EPRI	- Electric Power Research Institute

FEA	- Federal Energy Administration
FPC	- Federal Power Commission
FTFB	- Ford Technical Fix, Base Case Scenario
GAL	- Gallon
GNP	- Gross National Product
GSA	- General Services Administration
GWe	- Gigawatt electrical
HP	- Horsepower
JCAE	- Joint Committee on Atomic Energy
KWe	- Kilowatt electrical
KWh	- Kilowatt-hour
LB	- Pounds
MCFD	- Million Cubic Feet Per Day (Also MMCFD)
MHD	- Magnetohydrodynamics
MIT	- Massachusetts Institute of Technology
MSFC	- Marshall Space Flight Center
MT	- Million Tons
MTPY	- Million Tons Per Year
MWe	- Megawatt electrical
MWth	- Megawatt thermal
NAE	- National Academy of Engineering
NASA	- National Aeronautics and Space Administration
NBS	- National Bureau of Standards
NCMP	- National Commission on Materials Policy
NEE	- Nuclear Electric Energy Economy (Westinghouse)
NGL	- Natural Gas Liquids
NPC	- National Petroleum Council
NSF	- National Science Foundation

OCR	- Office of Coal Research
OMB	- Office of Management and Budget
POCE	- Proof of Concept Experiments
Q	- 10^{18} BTU
QUAD	- Quadrillion BTU (BTU x 10^{15})
R & D	- Research and Development
SNG	- Substitute Natural Gas
TA	- Technology Assessment
TAPS	- Trans-Alaska Pipeline System
TCFY	- Trillion Cubic Feet Per Year
TVA	- Tennessee Valley Authority
ULCC	- Ultra Large Crude Carrier
U.S.	- United States of America
USGS	- U.S. Geological Survey
VLC	- Very Large Crude Carrier
YD	- Yards
ZEG	- Zero Energy Growth
ZPG	- Zero Population Growth

APPENDIX B. ENERGY SOURCES

B-1 OIL AND GAS

B-1-1 PRESENT PRODUCTION AND HISTORY

Oil and natural gas are essential to our present economy and are important in all energy production scenarios. The recent production history of crude petroleum, natural gas, and natural gas liquids is reviewed in Tables B-1, B-2, and B-3 respectively. In this connection Table B-7 is also of interest for it presents this production history for the qualitatively different areas of onshore lower forty eight states, offshore, and North Slope Alaska.

B-1-2 UNIT REQUIREMENTS

Requirements for finding and producing a BTU's worth of oil and gas include capital, manpower, and materials. It was found more convenient to assemble capital and manpower requirements directly for each scenario than to work via unit requirements; these requirements are put together in Appendix B-1-3. (One possible manpower bottleneck is the number of geologists and geophysicists available. This might delay the evaluation of potential offshore additions, but the size of this effect is uncertain [OGJ-74-3].) The material requirements for producing oil from an exploratory or development well are much smaller than those for finding the oil in the first place, though if secondary and tertiary (water flooding and other) methods become the rule this will change somewhat. The major requirements are then those for drilling. They are the steel for the drill rig itself, steel for the casing that goes in the hole, and cement that also goes in the hole. Onshore rigs use about 500 to 2000 tons of steel; offshore rigs use between 5000 and 15,000 tons, the difference being the ship that is constructed to carry the rig. The costs also reflect this: up to about two million dollars for an onshore rig versus about forty to fifty million dollars for one that can work offshore. Typical holes onshore are nearly 5000 feet deep today, offshore they are twice this. The steel and cement needed for a hole are simply proportional to the depth, ranging from 200 to 500 tons of steel and approximately 3000 sacks of cement for a 10,000 foot hole.

So, in order to project the requirements for finding a given amount of oil and/or gas we need to know how many rigs are operative on and offshore, how many holes are drilled on and offshore, and what the average depth is. Tables B-4, B-5 contain the pertinent history and our estimates as to future developments. These estimates are consistent with present trends but reflect the opinion that we have run out of easily locatable oil onshore (except in Alaska) and that offshore drilling will proceed fast enough to drill the most promising areas by the late nineteen eighties.

TABLE B-1. - PAST PRODUCTION OF CRUDE PETROLEUM
(Natural Gas Liquids not included)

Year	U.S. Production (10^6 42-gal bbls)	U.S. Production (10^{12} Btu)*	Crude Imports (10^6 42-gal bbls)	Crude Exports (10^6 42-gal bbls)	Proved Reserves Estimated at year end (10^6 42-gal bbls)	Reserves / Production	Refined Products (10^6 42-gal bbls) Imports	Refined Products (10^6 42-gal bbls) Exports	Net Totals Imports (10^6 42-gal bbls)
1950	1974[a]	11,449	177.7[a]	34.8[a]	25,268[a]	12.8	133[b]	76[b]	200
1955	2484[a]	14,407	285.4[a]	11.6[a]	30,012[a]	12.1	170[b]	123[b]	321
1960	2575[b]	14,935	372[b]	3[b]	31,613[c]	12.3	293[b]	71[b]	591
1965	2849[b]	16,524	452[b]	1[b]	31,352[c]	11.0	449[b]	67[b]	833
1968	3329[b]	19,308	472[b]	2[b]	30,707[c]	9.2	567[b]	83[b]	954
1969	3372[b]	19,558	514[b]	1[b]	29,632[c]	8.8	641[b]	83[b]	1071
1970	3517[b]	20,399	483[b]	5[b]	39,001[c]	11.1	765[b]	89[b]	1154
1971	3454[b]	20,033	613[b]	1[b]	38,063[c]	11.0	819[b]	81[b]	1350
1972	3455[f]	20,039			36,339[c]	9.5			
1973	3367[d]	19,529			35,300[e]	10.5			

*5.8×10^6 Btu/bbl crude (average)

a. Bu. Cen. -60
b. DOC-73
c. Env. Info. -73
d. OGJ-73-2
e. OGJ-74-2
f. IPE-73

TABLE B-2. PAST PRODUCTION OF NATURAL GAS

Year	Marketed U.S. Production (10^9 cu ft)	Marketed U.S. Production (10^{12} Btu)*	Imports (10^9 cu ft)	Exports (10^9 cu ft)	Net Imports (10^9 cu ft)	Proved Reserves Estimated at year end (10^9 cu ft)	Reserves / Production
1950	6,282[a]	6,502	0[b]	26[b]	-26	185,593[a]	29.5
1955	9,405[a]	9,734	11[b]	31[b]	-20	223,697[a]	23.8
1960	12,771[b]	13,218	156[b]	11[b]	145	263,759[b]	20.7
1965	16,040[b]	16,601	456[b]	26[b]	430	288,100[c]	17.9
1968	19,322[b]	19,998	652[b]	94[b]	558	282,100[c]	14.6
1969	20,698[b]	21,422	727[b]	51[b]	676	269,900[c]	13.0
1970	21,921[b]	22,688	821[b]	70[b]	751	290,746[b]	13.3
1971	22,493[b]	23,280	935[b]	80[b]	855	278,806[b]	12.4
1972	22,512[h]	23,300				266,085[e]	11.6
1973						249,950[e]	

*1035 Btu/cu ft (average)

a. Bu. Cen. -60
b. DOC-73
c. Env. Info. -73
d. OGJ-73-2
e. OGJ-74-2
f. IPE-73
h. AGA-72-1

TABLE B-3. - PAST PRODUCTION OF NATURAL GAS LIQUIDS

Year	U.S. Production (10^6 42-gal bbls)	U.S. Production (10^{12} Btu)*	Proved Reserves Estimated at year end (10^6 42-gal bbls)	Reserves / Production
1950	182[a]	730		
1955	281[a]	1,127		
1960	340[b]	1,364		
1965	442[b]	1,773		
1968	550[b]	2,206		
1969	580[b]	2,326		
1970	606[b]	2,431		
1971	618[b]	2,479	7,304[c]	11.8
1972			6,787[e]	
1973			6,455[e]	

*4.011 x 10^6 Btu/bbl (average)

a. Bu. Cen. -60
b. DOC-73
c. Env. Info. -73
d. OGJ-73-2
e. OGJ-74-2

TABLE B-4 ONSHORE DRILLING HISTORY AND PROJECTIONS

5 Year Period	Additions[a] (BTU x 10^{15})	Active[b] Rigs (Average)	Wells[c] Drilled (x 10^3)	Additions per rig (BTU x 10^{12})	Additions per well (BTU x 10^9)	Average Depth (feet)
1956-60	85	1860	250	45.6	340	4,150
1961-65	73	1470	208	49.6	350	4,350
1966-70	73	1030	146	71.0	500	4,850
1971-75				50	500	5,150
1976-80				43.5	450	5,500
1981-85				37	400	5,850
1986-90				33	400	6,200
1991-95				27.8	350	6,550
1996-2000				25	300	6,900

a) Table B-8

b) OGJ-68 and OGJ-73-3

c) SPRD-73

TABLE B-5 OFFSHORE DRILLING HISTORY AND PROJECTIONS

5 Year Period	Additions (BTU x 10^{15})	Active Rigs (Average)	Wells Drilled (x 10^3)	Additions per rig (BTU x 10^{12})	Additions per well (BTU x 10^{12})	Average Depth (feet)
1956-60	7	54	2.5	130	2.8	9,600
1961-65	13	84	4.2	155	3.1	10,300
1966-70	25	121	6.0	206	4.2	9,700
1971-75				200	4.5	10,000
1976-80				167	4.5	10,000
1981-85				125	4.2	10,000
1986-90				91	3.8	10,000
1991-95				67	3.4	10,000
1996-2000				53	3.0	10,000

[a] Table B-8

[b] OGJ-68 and OGJ-73-3

[c] SPRD-73

B-1-3 FUTURE REQUIREMENTS ON ALTERNATIVE PATHS

Paths, as referred to in this section, will be the annual requirements for domestic oil and natural gas liquids (NGL) and domestic natural gas from now until the year 2000. To minimize unnecessary detail, 5-year time increments will be used. The objective in this section is to determine, for each path, the requirements in terms of facilities, manpower, capital, materials, and critical equipment to provide the fuel specified by the path.

Each path specifies only the total domestic oil and total domestic gas to be supplied in the future without specifying what mix of sources for these fuels will be appropriate. In order to obtain a reasonably valid estimate of the requirements to provide the fuels it is necessary to dissect the paths into the likely mix of sources. For example, the requirements to provide oil from offshore sources differ substantially from those for onshore, which in turn differ somewhat from those for Alaska's North Slope area. Therefore, the total oil requirement is divided into an estimated mix of these three sources to provide a more refined estimate of requirements. Natural gas sources are similarly divided into onshore, offshore, and North Slope sources. From the amount of fuel provided by each regional source, combined with the requirements per unit of fuel output (determined in Section B-1-2) the detailed requirements are ascertained. In all tables and graphs, historical trends since 1950 are included with the future projections for comparison.

The major onshore, offshore, and Alaska North Slope future resource areas are indicated in Figure B-1. The proposed oil and natural gas pipeline from Alaska's North Slope are not shown here, but are discussed in Appendix D. In addition to the onshore area in the vicinity of Prudhoe Bay there is a considerable offshore area with great potential on Alaska's North Slope [Cram-71]. The onshore areas with potential for discovery of more oil and gas are essentially the same areas that are now producing. The most promising offshore areas are in the Gulf of Mexico, off Southern California, and around Alaska [Kash-73, Appendix C].

Oil and Gas from Alaska's North Slope

Production of oil and gas in the Alaska North Slope area was assumed to be limited by the availability of pipelines and by the extent of the total resource. Oil pipeline capacities were assumed to be increased by steps starting with 600,000 bbl/day about 1978, increasing to 1,200,000 bbl/day about 1982 and 2,000,000 bbl/day by about 1988. These capacities will be provided by a single crude oil pipeline. It is assumed that, because of the large step in required cost for a second pipeline, no additional capacity will be added until after 2000. A gradual rise in oil production is used instead of step increases because of the uncertainty of the dates of the steps. It is assumed that North Slope discoveries of oil for the remainder of the century will approximately equal those made so far, and will result from steady, low-level exploration. It is also assumed that the North Slope Naval Petroleum Reserves will not be opened for development before 2000. A natural gas pipeline is anticipated to be completed in about 1979 with total capacity of 1.45 trillion cu ft/yr. Present plans are to construct this line in cooperation with Canada with about one-third of the capacity being used by Canada leaving two-thirds of the capacity for the U. S.

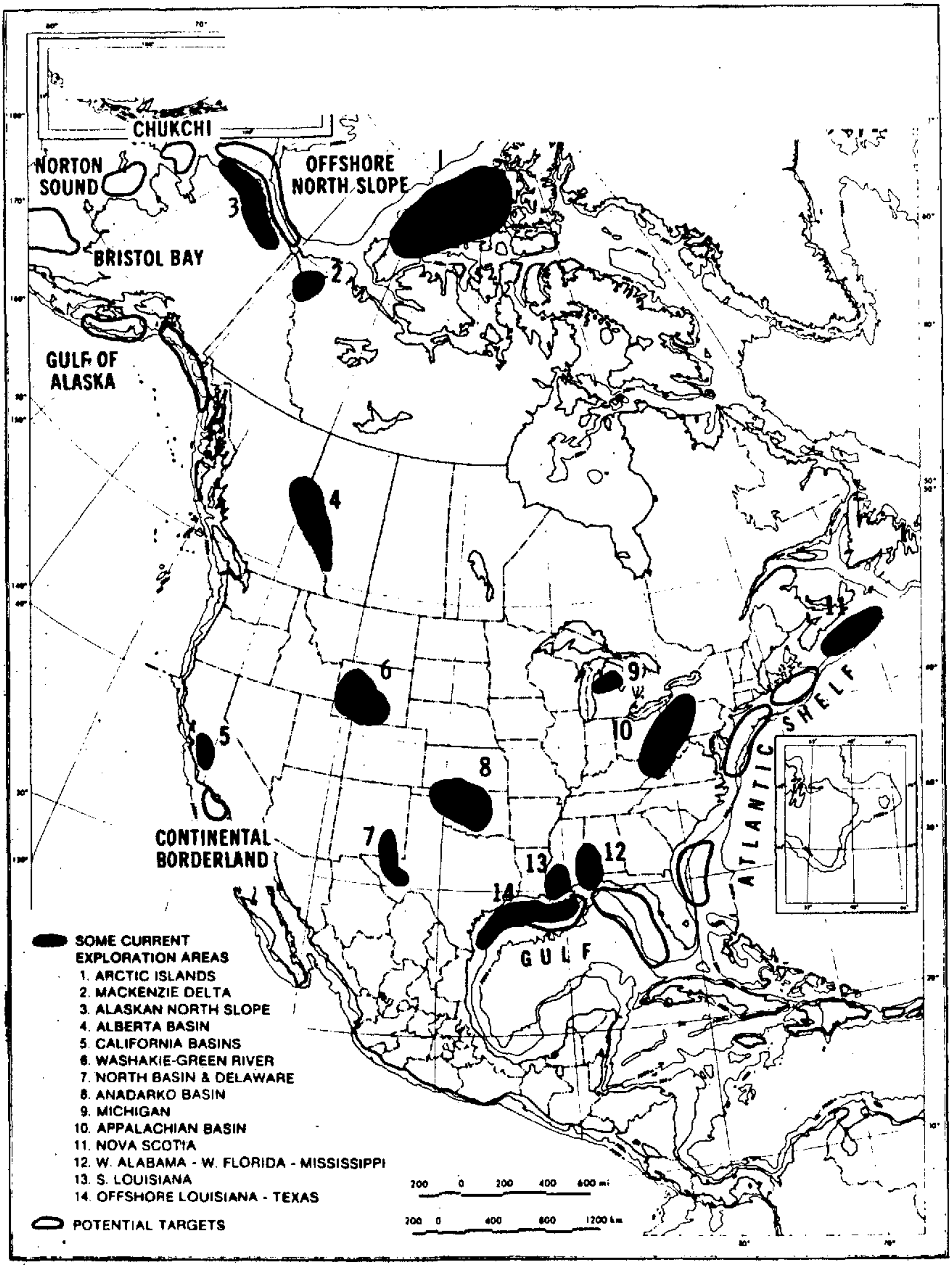

FIGURE B-1 AREAS WHERE ADDITIONAL OIL AND GAS ARE LIKELY TO BE FOUND [Shell-73]

Because this first pipeline would only exploit a very small part of the reserves presently discovered on the North Slope, a second pipeline of 1.45 trillion cu. ft/yr capacity will probably be built by about 1987. As in the case of oil, a gradual rise in natural gas production is used because of the uncertainty of the dates of completion of pipelines. It is assumed that North Slope discoveries of natural gas will also approximate those made so far, and will result from steady, low-level exploration. Recent estimates indicate as much as 300 x 10^{12} cu ft of natural gas may be found at Prudhoe Bay [McNeil-74]. If this estimate is realized, many more than two lines will be required and production will be much higher. However, it is difficult to assess the validity of such estimates at the present stage of exploration.

Oil from Increased Recovery from Old Wells

A substantial part of onshore additions to reserves will come from increased recovery of both old and new discoveries. Approximately 880,000 x 10^{12} BTU have been recovered from past oil discoveries [Risser-73] at an average recovery rate on the order of 31 percent. Increased oil prices are expected to stimulate use of presently known secondary and tertiary recovery methods and increase the recovery rate to about 40 percent. This would imply 256,000 x 10^{12} BTU (about 46 x 10^9 bbl) would be made available from old wells in addition to the increased recovery from all new finds. Of course not all of the old wells could or would be exploited to the 40 percent level because of small size or because they have been abandoned in unrecoverable condition. However, increased recovery will still be an important future source of oil. A Ford Foundation Energy Policy Project survey of oil producers yielded an estimate of 55 x 10^9 bbl of increases to reserves by 2000 from increased recovery at the new higher oil prices [Saulter-74]. This, of course, includes increased recovery of new oil which will be discovered between now and the end of the century (as well as of oil from old wells). For this study increased recovery of new oil discoveries is included in the additions to reserves from the new discoveries. However, old wells which are reopened because of higher prices making secondary and tertiary recovery economically feasible are accounted separately. It is assumed that about one-fourth of the oil available from improved recovery in these old wells will actually be recovered by 2000. Therefore, added production of about 64 x 10^{15} BTU of production from old wells is distributed in the period from now to 2000.

Refineries

The United States has imported refined oil products in rapidly increasing quantities during the years 1950-74 [DOC-73]. This argues for considerably increased refining capacity in this country so that some of the refined product imports could be replaced by crude. Against this conclusion stand two recent developments: (1) Middle Eastern oil producing countries now have a large refining capacity, so political considerations will probably force continued imports of refined products as long as crude oil is imported; (2) United States energy policies since the 1973 oil embargo involve decreasing reliance on oil imports in any form.

When the present United States refinery capacity is augumented by ex-

pansion now planned to be completed in 1978 the total will be nearly 16 million barrels per day [OGJ-74-1]. This is more than 33 quads per year, a capacity sufficient for the demand incorporated in all three scenarios considered in this report. Table B-6, illustrates this. Thus neither impacts nor requirements directly related to refineries are considered.

Ford Technical Fix - Base Case Scenario

The total amounts of domestic oil and natural gas required by this scenario are indicated in the second column of Table B-7. The paths require substantial growth of output from domestic sources for both of these fuels. This growth must be provided from the traditional onshore sources, the forthcoming Alaska North Slope source, and substantial new offshore discoveries.

The assumptions used in breaking down the fuel supplies by source are summarized here. Discoveries of oil and NGL and natural gas onshore have been declining since 1955. It is assumed that the onshore discovery rate will level out for a few years because of increased exploration and , for oil, increased use of secondary and tertiary recovery resulting from recent price increases. After about 1975, discovery of oil and gas onshore will continue to decline because the remaining resources are located in the smaller, more difficult to locate, and deeper pockets.

Onshore oil and gas production will begin to decline immediately because of the declines of onshore discovery over the past 10 years. Offshore discoveries and production are rising. Also there are several offshore areas off Florida, Alaska, and California which seem to hold great potential (in addition to the better known Gulf of Mexico areas). These unexplored or partially explored offshore areas are expected to have the greatest potential to provide a large part of required future discoveries. All oil and gas required by the path but not expected to be provided by onshore and North Slope sources was assumed to come from offshore.

The major general assumption was that the ratio of total reserves to total production will continue to be maintained by discoveries at 10 or more through 2000. Because the onshore ratio will be declining due to depletion, the ratio offshore will increase to compensate. Depletion of all domestic oil and gas will not yet be evident by 2000, but will be evidenced by declining reserve/production ratio some time after 2000.

The production scenario resulting from these assumptions is given in Table B-7. Tables B-8, B-9 and B-10 give the projected exploration and discovery in terms of additions to reserves. Tables B-9 and B-10 include cumulative discoveries required until the end of the century and U.S. Geological Survey and Mobil estimates of recoverable undiscovered oil and gas for comparison. The U.S.G.S. figures indicate that the projected discovery schedule may well be feasible. However, Mobil and some other industry estimators believe the U.S.G.S. is too optimistic in its estimates [Gillette-74]. If Mobil is correct, the projections in Tables B-9 and B-10 have about the correct balance between onshore and offshore discoveries, but require far more new oil and gas than is actually available. If Mobil is correct, the domestic oil and gas required by the Ford Foundation Technical Fix Base Case scenario is simply not available.

TABLE B-6 REFINERY CAPACITY (QUADS/YEAR)

		1975	1980	1985	1990	1995	2000
Refinery Capacity[a]		-	33.6	33.6	33.6	33.6	33.6
NEE	Total Oil	34	35	30	26	23	22
	Crude Oil*	27.5	28	26	23	20.5	20
FTF	Total Oil	-	34	26.4	27	29	31.2
	Crude Oil*	-	28	24.6	25.7	27.6	29.7
Alternate FTF	Total Oil	-	38.7	36.5	33.8	32.8	31.2
	Crude Oil*	-	31.7	32.4	32.2	31.2	29.7

*Crude Oil is estimated as 95% of domestic production plus 50% of import. The current trends are 90% and decreasing, and 60% and rising for domestic and imported oil respectively, so this is an overestimate.

[a] OGJ-74-1

TABLE B-7 DOMESTIC PRODUCTION OF OIL AND NATURAL GAS (FORD TECHNICAL FIX-BASE CASE)

Year	Total Annual Production (10^{15} BTU)	Production Onshore (10^{15} BTU)	Production Offshore (10^{15}BTU)	Production North Slope (10^{15} BTU)	Production from old wells (10^{15} BTU)
Oil & NGL					
1950	12.2	12.0	.2	0	
1955	15.5	14.9	.6	0	
1960	16.3	15.5	.8	0	
1965	18.3	16.8	1.5	0	
1970	22.8	19.4	3.4	0	
1975	23	17.6	5.0	0	.4
1980	24	14.5	7.1	1.2	1.2
1985	25.2	12.1	8.6	2.5	2.0
1990	27	10.6	9.6	4.2	2.6
1995	29	9.8	12.2	4.2	2.8
2000	31.2	9.2	15.2	4.2	2.6
Natural Gas					
1950	6.5	6.5	0	0	
1955	9.7	9.6	.1	0	
1960	13.2	12.7	.5	0	
1965	16.6	15.0	1.6	0	
1970	22.7	19.6	3.1	0	
1975	23.0	18.0	5.0	0	
1980	23.2	15.0	7.7	.5	
1985	26.6	14.5	11.1	1	
1990	27.5	12.0	13.0	2.5	
1995	28.5	10.5	15.5	2.5	
2000	28.5	9.5	16.5	2.5	

TABLE B-8 DISCOVERY OF OIL AND NATURAL GAS (FORD TECHNICAL FIX-BASE CASE)

Year	Total Year End Reserves* (10^{15} BTU)	Reserves Onshore* (10^{15} BTU)	Reserves Offshore* (10^{15} BTU)	Reserves North Slope* (10^{15} BTU)	Reserves from old wells (10^{15} BTU)
Oil & NGL					
1950	156 (12.8)	153 (12.8)	2.6 (12.8)	0	
1955	188 (12.1)	181 (12.1)	7.3 (12.1)	0	
1960	201 (12.4)	191 (12.3)	9.9 (12.3)	0	
1965	201 (11.0)	184 (11.0)	16.5 (11.0)	0	
1970	253 (11.1)	167 (8.6)	29.9 (8.8)	56	
1975	250 (10.9)	140 (8.0)	45 (9.0)	56	8
1980	268 (11.2)	120 (8.6)	65 (9.3)	64	19
1985	291 (11.6)	111 (9.4)	92 (10.7)	65(26)	24
1990	311 (11.5)	108 (10.2)	123 (12.8)	59(14)	21
1995	323 (11.1)	107 (10.9)	152 (12.5)	49(11.6)	16
2000	325 (10.4)	104 (11.3)	174 (11.4)	39(9.3)	9
Natural Gas					
1950	192 (29.6)	190 (29)	2	0	
1955	231 (23.8)	227 (23.6)	4 (40)	0	
1960	275 (20.9)	263 (20.7)	12 (24)	0	
1965	281 (17.0)	251 (16.7)	30 (19)	0	
1970	301 (13.2)	218 (11.1)	55 (17.8)	28	
1975	282 (12.3)	174 (9.7)	80 (16.0)	28	
1980	286 (12.3)	142 (9.5)	112 (14.6)	33	
1985	291 (10.9)	116 (8.0)	141 (12.7)	35(35)	
1990	296 (10.8)	95 (7.8)	170 (13.0)	32(12.8)	
1995	301 (10.6)	81 (7.7)	196 (12.6)	25(10.0)	
2000	309 (10.8)	68 (7.2)	225 (13.6)	18(7.2)	

*Reserve/production ratio indicated in parentheses.

TABLE B-8 (CONT) DISCOVERY OF OIL AND NATURAL GAS (FORD TECHNICAL FIX-BASE CASE)

5-year Period	5-year Total Additions to Reserves (10 BTU)	Additions Onshore (10 BTU)	Additions [Offshore] (10 BTU)	Additions [North Slope] (10 BTU)	Additions from old wells (10 BTU)
Oil & NGL					
1951-55	101	95	6	0	
1956-60	92	85	7	0	
1961-65	86	73	13	0	
1966-70	154	73	25	56	
1971-75	112	66	36	0	10
1976-80	136	60	50	11	15
1981-85	146	58	66	11	11
1986-90	150	54	76	11	9
1991-95	151	50	82	11	8
1996-2000	150	44	88	11	7
Natural Gas					
1951-55	80	77	4	0	
1956-60	101	92	9	0	
1961-65	80	57	23	0	
1966-70	118	53	37	28	
1971-75	95	50	45	0	
1976-80	120	50	64	6	
1981-85	130	48	76	6	
1986-90	140	45	89	6	
1991-95	145	42	97	6	
1996-2000	150	38	106	6	

TABLE B-9 OIL AND NGL ADDITIONS TO RESERVES FROM NEW DISCOVERIES (FORD TECHNICAL FIX-BASE CASE)

Period	Total Additions* (10^9 Bbl)	Cumulative from 1970	Additions Onshore (10^9 Bbl)	Cumulative from 1970	Additions Offshore (10^9 Bbl)	Cumulative from 1970	Additions North Slope (10^9 Bbl)	Cumulative from 1970
1951-55	18.4		17.3		1.1		0	
1956-60	16.7		15.5		1.3		0	
1961-65	15.6		13.3		2.4		0	
1966-70	28.0		13.3		4.6		10.2	
1971-75	18.6	18.6	12.0	12.0	6.5	6.5	0	0
1976-80	22.0	40.6	10.9	22.9	9.1	15.6	2	2
1981-85	24.6	65.2	10.6	33.5	12.0	27.6	2	4
1986-90	25.6	90.8	9.8	43.3	13.8	41.4	2	6
1991-95	26.0	116.8	9.1	52.4	14.9	56.3	2	8
1996-2000	26.0	142.8	8.0	60.4	16.0	72.3	2	10

1974 ESTIMATES OF UNDISCOVERED RECOVERABLE OIL & NGL [Gillette-74]

	Total (10^9 Bbl)	Onshore (10^9 Bbl)	Offshore (10^9 Bbl)	Alaska (10^9 Bbl)
USGS	200-400	110-220	64-130	25-50
Mobil	88	13	54	21

*Excluding additions from old wells.

TABLE B-10 NATURAL GAS ADDITIONS TO RESERVES FROM NEW DISCOVERIES (FORD TECHNICAL FIX-BASE CASE)

Period	Total Additions (10^{12} cu ft)	Cumulative from 1970	Additions Onshore (10^{12} cu ft)	Cumulative from 1970	Additions Offshore (10^{12} cu ft)	Cumulative from 1970	Additions North Slope (10^{12} cu ft)	Cumulative from 1970
1951-55	78		74		4		0	
1956-60	98		89		9		0	
1961-65	77		55		22		0	
1966-70	114		51		36		27	
1971-75	92	92	48	48	44	44	0	0
1976-80	116	208	48	96	62	106	6	6
1981-85	126	334	46	142	73	179	6	12
1986-90	136	470	44	186	86	265	6	18
1991-95	140	610	41	227	94	359	6	24
1996-2000	145	755	37	264	102	461	6	30

1974 ESTIMATES OF UNDISCOVERED RECOVERABLE NATURAL GAS [Gillette-74]

	Total (10^{12} cu ft)	Onshore (10^{12} cu ft)	Offshore (10^{12} cu ft)	Alaska (10^{12} cu ft)
USGS	1000-2000	500-1000	395-790	105-210
Mobil	443	65	274	104

Historically oil and gas have been found and produced together. That is, natural gas has been found in conjunction with oil discoveries and has been developed and produced as the oil was developed and produced. In recent years there has been a developing effort to discover and produce gas in areas and formations favoring gas alone with no appreciable recoverable oil. In spite of this trend, it is likely that most discovery, development, and production of gas will be in conjunction with oil. Therefore the projections for the required equipment, materials, manpower, and capital are made for oil and gas together rather than separately.

Table B-11 gives the recent history and projections for drilling rig requirements. The number of active rigs in a given period is correlated with the total additions to reserves for the same period. The onshore additions per rig have been increasing over the last fifteen years, but it was assumed that this trend would reverse because of the greater difficulty expected in finding smaller pockets of oil and gas and deposits in regions where seismic exploration does not provide clues. The onshore additions per rig were assumed to decline to a level at the end of the century which is about 35 percent of the level in recent years. The offshore additions per rig have been about three times the onshore ratio and also increasing. The ratio offshore is assumed to level off over the next 5 to 10 years and then decline. At the end of the century the offshore additions per rig are assumed to be about the same as the 1965 ratio onshore (about 26 percent of the current offshore level).

Table B-12 gives the history and projections for manpower, capital, and steel requirements to provide the oil and natural gas required by this scenario. The manpower required for petroleum and natural gas extraction is correlated to total production. Productivity of manpower in this area has been increasing significantly over the past 20 years (output per worker is increasing). It is assumed that productivity has reached its upper limit and will even begin to decline moderately because of the increased effort required in exploration. In refining the manpower is correlated to total oil production and the productivity has been increasing. It is assumed that refining productivity will level off at the present value.

The direct capital required for exploration and development was divided into exploration, development, and improved recovery costs. Exploration costs are correlated with the total number of active drillings rigs. The cost per rig is assumed to rise, because of the rapidly growing role of costly offshore exploration to about 1.8 times present costs (constant 1972 dollars) by the end of the century. Development costs are correlated with the totals of additions to reserves. These costs are expected to rise moderately, again because of the increased role of offshore oil and gas, to about 1.3 times present costs per unit of additions. Costs for improved recovery are correlated directly to the production of oil from old wells by secondary and tertiary methods.

Projections of steel and current requirements necessary for oil and gas exploration were made as follows. Each scenario outlines a production schedule for domestic oil. Using estimates described previously a schedule of <u>additions to reserves</u> onshore, offshore, and on the North Slope was obtained. The unit requirements in Tables B-4 and 5 were then used to project the number of wells and drill rigs required in each five year period. Steel and cement requirements for the wells were then found using the material of Appendix B-1-2. The ranges given

TABLE B-11 DRILLING RIG REQUIREMENTS TO PROVIDE OIL AND NATURAL GAS (FORD TECHNICAL FIX-BASE CASE)

Period	Average Number Active Rigs-Total	Ave. Active Rigs Onshore	Ave. Active Rigs Offshore	Ave. Active Rigs North Slope	New Onshore Rigs Req'd	New Offshore Rigs Req'd
1956-60	1914	1860	54	0	-	-
1961-65	1554	1470	84	0	560	44
1966-70	1157	1030	121	6	480	57
1971-75	1510	1320	180	6	640	90
1976-80	1690	1380	300	6	640	170
1981-85	2100	1560	530	6	880	310
1986-90	2470	1620	840	6	840	450
1991-95	3040	1800	1230	6	1000	600
1996-2000	3440	1760	1670	6	840	730

TABLE B-12 MANPOWER, CAPITAL, AND STEEL REQUIREMENTS TO PROVIDE OIL AND NATURAL GAS (FORD TECHNICAL FIX-BASE CASE)

Year	Total Manpower[a]	Total Engineers[b]	Exploration and Development Capital (10^6 '72 $)[c]	5-Year Period	5-Year Total Exp. and Dev. Capital (10^6 '72 $)	5-Year Total of New Steel (10^6 Tons)[d]	5-Year Total of cement (10^6 tons)[d]
1950	451,000						
1955	533,000						
1960	486,000						
1965	435,000						
1970	424,000	26,000	5,460				
1975	368,000	27,100	7,380	1971-75	32,100	39	11
1980	408,000	29,500	9,360	1976-80	41,800	43	13
1985	455,000	31,300	11,600	1981-85	52,300	51	15
1990	513,000	33,100	13,600	1986-90	63,100	53	17
1995	580,000	35,200	15,900	1991-95	73,800	61	18
2000	657,000	37,000	18,750	1996-2000	86,600	66	19

a) Total manpower employed in crude petroleum and natural gas extraction and petroleum refining. Source for 1950 through 1970: [DOL-72].

b) Total engineers employed in exploration, production, refining, and research for oil and gas. Source for 1970 (estimate based on 1967 data): [NPC-69].

c) Total direct expenditures for oil and gas exploration and development (omitting all overhead and taxes). Source for 1970: [SPRD-73]

d) Obtained by aggregating unit requirements as described in Appendix B-1-3.

there show that these projections can be off by as much as a factor of two. The steel requirements for drill rigs can be obtained once the number of new drillings needed in each five year period is known.

The number of new drill rigs is obtained by assuming an 8 percent replacement rate onshore due to obsolescence and major breakdown. Since the average depth of holes is increasing onshore, obsolescence is presumably going to continue to be a problem. Offshore, a 1 percent to 4 percent replacement rate is assumed to reflect the variability in the likelihood of finding oil presumed by the scenarios and the lesser importance of obsolescence. The total amount of steel involved is small, however, so details of the computations are not given here, but instead are presented as an example in the table for onshore drillings in the FTFB, Table B-13.

Ford Technical Fix-Alternative Path Scenario

Tables B-14, B-15, B-16 and B-17 give the amounts of oil and gas which must be found and produced for this scenario. As was true for the FTFB path, the discovery requirements for oil and natural gas far exceed the Mobil estimates of undiscovered resources. However, if the U.S.G.S. estimates are correct, the requirements are likely to be quite feasible (Tables B-16 and B-17). Table B-18 gives the drilling rig requirements to provide the oil and gas for this scenario based on the same assumptions used for the FTFB path. Likewise manpower, capital, and steel requirements are given in Table B-19 based on the same assumptions used for the FTFB path. In all cases the same ratios of discoveries per rig, and productivities of manpower and capital as assumed in the FTFB path were used here. This scenario is characterized by higher requirements for oil and gas at an earlier period, but for the most part the requirements to provide the oil and gas are similar to those for the FTFB path.

Nuclear Electric Economy Scenario

Tables B-20, B-21, B-22, and B-23 give the amounts of oil and gas which must be found and produced for this scenario. In this case the amounts which must be found offshore and on the North Slope are within Mobil's estimates of the total resources, but the onshore requirements far exceed Mobil's estimates. Since the oil and gas requirements for this scenario are quite modest, they fall well below U.S.G.S. estimates and would be feasible if U.S.G.S. estimates are correct. Table B-24 gives the drilling rig requirements to provide the oil and gas for this scenario based on the same assumptions used for the FTFB path. Manpower, capital, and steel requirements are given in Table B-25 based on the same assumptions used for the FTFB path. In all cases the same ratios of discoveries per rig and productivities of manpower and capital as assumed in the FTFB path were used here. This scenario is characterized by much lower total amounts for oil and gas than the other two, and the requirements to provide the oil and gas are much more modest.

B-1-4 IMPACTS, OIL AND GAS EXPLORATION AND PRODUCTION

This section is devoted to those impacts of the development of United

TABLE B-13 NEW/RIGS IN FTF (BASE CASE) ONSHORE

Five Year Period	Average Number[a] of Rigs Active	Average Number[b] of Rigs	New Rigs[c] During Period	Sample Calculation
1956-60	1860	2000	-	Period: 1991-95
1961-65	1470	1800	560	New rigs added is the increase in average number of rigs (=200) plus the rigs added to replace old rigs (=(0.08)(5)(1/2)(1900 + 2100)) for a total of 200 + 800 = 1000.
1966-70	1030	1600	480	
1971-75	1320	1600	640	
1976-80	1380	1600	640	
1981-85	1560	1800	880	
1986-90	1620	1900	840	
1991-95	1800	2100	1000	
1996-2000	1760	2100	840	

a) OGJ-68 and OGJ-73-3

b) Assuming 85 percent utilization

c) Assuming 8 percent obsolescence

TABLE B-14 DOMESTIC PRODUCTION OF OIL AND NATURAL GAS (FORD TECHNICAL FIX-ALTERNATE PATH)

Year	Total Annual Production (10^{15} BTU)	Production Onshore (10^{15} BTU)	Production Offshore (10^{15} BTU)	Production North Slope (10^{15} BTU)	Production from Old Wells (10^{15} BTU)
Oil & NGL					
1950	12.2	12.0	.2	0	
1955	15.5	14.9	.6	0	
1960	16.3	15.5	.8	0	
1965	18.3	16.8	1.5	0	
1970	22.8	19.4	3.4	0	
1975	25	18.6	6.0	0	.4
1980	27.3	17.4	7.5	1.2	1.2
1985	31.4	16.0	10.9	2.5	2.0
1990	33.8	12.8	14.2	4.2	2.6
1995	32.8	10.3	15.5	4.2	2.8
2000	31.2	8.2	16.2	4.2	2.6
Natural Gas					
1950	6.5	6.5	0	0	
1955	9.7	9.6	.1	0	
1960	13.2	12.7	.5	0	
1965	16.6	15.0	1.6	0	
1970	22.7	19.6	3.1	0	
1975	24.4	19.2	5.2	0	
1980	26.1	17.0	8.6	.5	
1985	30	15.0	14.0	1	
1990	32.6	13.0	17.1	2.5	
1995	31.6	11.0	18.1	2.5	
2000	29.7	9.6	17.6	2.5	

TABLE B-15 DISCOVERY OF OIL AND NATURAL GAS (FORD TECHNICAL FIX-ALTERNATE PATH)

Year	Total Year End Reserves (10^{15}BTU)	Reserves Onshore* (10^{15}BTU)	Reserves Offshore* (10^{15}BTU)	Reserves North Slope* (10^{15}BTU)	Reserves from Old Wells (10^{15}BTU)	5-Year Period	5-Year Total Additions to Reserves (10^{15}BTU)	Additions Onshore (10^{15}BTU)	Additions Offshore (10^{15}BTU)	Additions North Slope (10^{15}BTU)	Additions from Old Wells (10^{15}BTU)
Oil & NGL											
1950	156 (12.8	153 (12.9)	2.6 (12.8)	0							
1955	188 (12.1)	181 (12.1)	7.3 (12.1)	0		1951-55	101	95	6	0	
1960	201 (12.4)	191 (12.3)	9.9 (12.3)	0		1956-60	92	85	7	0	
1965	201 (11.0)	184 (11.0)	16.5 (11.0)	0		1961-65	86	73	13	0	
1970	253 (11.1)	167 (8.6)	29.9 (8.8)	56		1966-70	154	73	25	56	
1975	258 (10.3)	147 (7.9)	46 (7.7)	56	8	1971-75	125	75	40	0	10
1980	282 (10.3)	125 (7.2)	73 (9.7)	64	19	1976-80	155	68	61	11	15
1985	310 (9.8)	103 (6.5)	118 (10.8)	65 (26)	24	1981-85	175	62	91	11	11
1990	332 (9.7)	90 (7.0)	162 (11.4)	59 (14)	21	1986-90	185	59	106	11	9
1995	341 (10.4)	88 (8.5)	189 (12.2)	49 (11.6)	16	1991-95	175	56	100	11	8
2000	341 (10.9)	96 (11.7)	197 (12.2)	39 (9.3)	9	1996-2000	160	54	88	11	7
Natural Gas											
1950	192 (29.6)	190 (29)	2	0							
1955	231 (23.8)	227 (23.6)	4 (40)	0		1951-55	80	77	4	0	
1960	275 (20.9)	263 (20.7)	12 (24)	0		1956-60	101	92	9	0	
1965	281 (17.0)	251 (16.7)	30 (19)	0		1961-65	80	57	23	0	
1970	301 (13.2)	218 (11.1)	55 (17.8)	28		1966-70	118	53	37	28	
1975	293 (12.0)	178 (9.3)	87 (16.7)	28		1971-75	110	57	53	0	
1980	303 (11.6)	141 (8.3)	129 (15.0)	33		1976-80	136	53	77	6	
1985	318 (10.6)	111 (7.4)	172 (12.2)	35 (35)		1981-85	155	50	99	6	
1990	327 (10.0)	88 (6.8)	206 (12.0)	32 (12.8)		1986-90	165	47	112	6	
1995	321 (10.1)	73 (6.6)	223 (12.3)	25 (10.0)		1991-95	155	44	105	6	
2000	318 (10.6)	64 (6.7)	234 (13.2)	18 (7.2)		1996-2000	148	42	100	6	

*Reserve/production ratio indicated in parentheses

TABLE B-16 OIL & NGL ADDITIONS TO RESERVES FROM NEW DISCOVERIES (FORD TECHNICAL FIX-ALTERNATE PATH)

Period	Total Additions* (10^9 Bbl)	Cumulative from 1970	Additions Onshore (10^9 Bbl)	Cumulative from 1970	Additions Offshore (10^9 Bbl)	Cumulative from 1970	Additions North Slope (10^9 Bbl)	Cumulative from 1970
1951-55	18.4		17.3		1.1		0	
1956-60	16.7		15.5		1.3		0	
1961-65	15.6		13.3		2.4		0	
1966-70	28.0		13.3		4.6		10.2	
1971-75	20.9	20.9	13.6	13.6	7.3	7.3	0	0
1976-80	25.5	46.4	12.4	26.0	11.1	18.4	2	2
1981-85	29.9	76.3	11.3	37.3	16.6	35.0	2	4
1986-90	32.0	108.3	10.7	48.0	19.3	54.3	2	6
1991-95	30.4	138.7	10.2	58.2	18.2	72.5	2	8
1996-2000	27.9	166.6	9.8	68	16.0	88.5	2	10

1974 ESTIMATES OF UNDISCOVERED RECOVERABLE OIL & NGL [Gillette-74]

	Total (10^9 Bbl)	Onshore (10^9 Bbl)	Offshore (10^9 Bbl)	Alaska (10^9 Bbl)
USGS	200-400	110-220	64-130	25-50
Mobil	88	13	54	21

*Excluding Additions from Old Wells.

TABLE B-17 NATURAL GAS ADDITIONS TO RESERVES FROM NEW DISCOVERIES (FORD TECHNICAL FIX-ALTERNATE PATH)

Period	Total Additions (10^{12}cu ft)	Cumulative from 1970	Additions Onshore (10^{12}cu ft)	Cumulative from 1970	Additions Offshore (10^{12}cu ft)	Cumulative from 1970	Additions North Slope (10^{12} cu ft)	Cumulative from 1970
1951-55	78		74		4		0	
1956-60	98		89		9		0	
1961-65	77		55		22		0	
1966-70	114		51		36		27	
1971-75	106	106	55	55	51	51	0	0
1976-80	132	238	51	106	75	126	6	6
1981-85	150	388	48	154	96	222	6	12
1986-90	160	548	46	200	108	330	6	18
1991-95	150	698	43	243	102	432	6	24
1996-2000	143	841	41	284	97	529	6	30

1974 ESTIMATES OF UNDISCOVERED RECOVERABLE NATURAL GAS [Gillette-74]

	Total (10^{12}cu ft)	Onshore (10^{12}cu ft)	Offshore (10^{12}cu ft)	Alaska (10^{12}cu ft)
USGS	1000-2000	500-1000	395-790	105-210
Mobil	443	65	274	104

TABLE B-18 DRILLING RIG REQUIREMENTS TO PROVIDE OIL AND NATURAL GAS (FORD TECHNICAL FIX-ALTERNATE PATH)

Period	Average Number of Active Rigs Total	Average Active Rigs Onshore	Average Active Rigs Offshore	Average Active Rigs North Slope	New Onshore Rigs Req'd	New Offshore Rigs Req'd
1956-60	1914	1860	54	0		
1961-65	1554	1470	84	0	560	44
1966-70	1157	1030	121	6	480	57
1971-75	1710	1500	200	6	820	110
1976-80	1930	1560	360	6	820	220
1981-85	2500	1670	820	6	860	480
1986-90	2950	1770	1170	6	960	400
1991-95	3610	2100	1500	6	1320	400
1996-2000	3840	2160	1670	6	1060	250

TABLE B-19 MANPOWER, CAPITAL, AND STEEL REQUIREMENTS TO PROVIDE OIL AND NATURAL GAS (FORD TECHNICAL FIX-ALTERNATE PATH)

Year	Total Manpower[a]	Total Engineers[b]	Exploration and Development Capital[c] (10^6 '72 $)	5-Year Period	5-Year Total Exp. & Dev. Capital (10^6 '72 $)	5-Year Total of New Steel (10^6 Tons)[d]	5-Year Total of Cement (10^6 Tons)[d]
1950	451,000						
1955	533,000						
1960	486,000						
1965	435,000						
1970	424,000	26,000	5,460				
1975	400,000	29,600	8,420	1971-75	34,600	43	13
1980	463,000	33,400	10,600	1976-80	47,500	50	15
1985	564,000	38,400	13,800	1981-85	61,000	58	17
1990	642,000	41,200	16,300	1986-90	75,100	62	18
1995	655,000	40,000	19,200	1991-95	88,800	68	20
2000	656,000	37,800	20,600	1996-2000	99,200	77	22

a)Total manpower employed in crude petroleum and natural gas extraction and petroleum. Source for 1950 through 1970: [DOL-72].

b)Total engineers employed in exploration, production, refining, and research for oil and gas. Source for 1970 (estimate based on 1967 data): [NPC-69].

c)Total direct expenditures for oil and gas exploration and development (omitting all overhead and taxes). Source for 1970: [SPRD-73].

d)Obtained by aggregating unit requirements as described in Appendix B-1-3.

TABLE B-20 DOMESTIC PRODUCTION OF OIL AND NATURAL GAS (NUCLEAR ELECTRIC ECONOMY)

Year	Total Annual Production (10^{15} BTU)	Production Onshore (10^{15} BTU)	Production Offshore (10^{15} BTU)	Production North Slope (10^{15} BTU)	Production from Old Wells (10^{15} BTU)
<u>Oil & NGL</u>					
1950	12.2	12.0	.2	0	
1955	15.5	14.9	.6	0	
1960	16.3	15.5	.8	0	
1965	18.3	16.8	1.5	0	
1970	22.8	19.4	3.4	0	
1975	26	19.6	6.0	0	.4
1980	25	14.8	7.8	1.2	1.2
1985	24	11.1	8.4	2.5	2.0
1990	22	7.7	7.5	4.2	2.6
1995	20	5.9	7.1	4.2	2.8
2000	20	5.9	7.3	4.2	2.6
<u>Natural Gas</u>					
1950	6.5	6.5	0	0	
1955	9.7	9.6	.1	0	
1960	13.2	12.7	.5	0	
1965	16.6	15.0	1.6	0	
1970	22.7	19.6	3.1	0	
1975	22	16.8	5.2	0	
1980	22	13.2	8.3	.5	
1985	23	10.8	11.2	1	
1990	18	5.9	9.6	2.5	
1995	13	4.3	6.2	2.5	
2000	9	2.6	3.9	2.5	

TABLE B-21 DISCOVERY OF OIL AND NATURAL GAS (NUCLEAR ELECTRIC ECONOMY

Year	Total Year End Reserves (10^{15}BTU)	Reserves Onshore* (10^{15}BTU)	Reserves Offshore* (10^{15}BTU)	Reserves North Slope* (10^{15}BTU)	Reserves from Old Wells (10^{15}BTU)	5-Year Period	5-Year Total Additions to Reserves (10^{15}BTU)	Additions Onshore (10^{15}BTU)	Additions Offshore (10^{15}BTU)	Additions North Slope (10^{15}BTU)	Additions from Old Wells (10^{15}BTU)
Oil & NGL											
1950	156 (12.8)	153 (12.8)	2.6 (12.8)	0							
1955	188 (12.1)	181 (12.1)	7.3 (12.1)	0		1951-55	101	95	6	0	
1960	201 (12.4)	191 (12.3)	9.9 (12.3)	0		1956-60	92	85	7	0	
1965	201 (11.0)	184 (11.0)	16.5 (11.0)	0		1961-65	86	73	13	0	
1970	253 (11.1)	167 (8.6)	29.9 (8.8)	56		1966-70	154	73	25	56	
1975	246 (9.5)	137 (7.1)	44 (7.3)	56	8	1971-75	115	68	37	0	10
1980	243 (9.7)	105 (7.1)	54 (6.9)	64	19	1976-80	125	54	45	11	15
1985	240 (10.0)	85 (7.7)	66 (7.9)	65 (26)	24	1981-85	119	45	52	11	11
1990	236 (10.7)	77 (10.0)	78 (10.4)	59 (14)	21	1986-90	110	39	51	11	9
1995	227 (11.4)	74 (12.5)	88 (12.4)	49 (11.6)	16	1991-95	95	30	46	11	8
2000	205 (10.2)	63 (10.7)	93 (12.7)	39 (9.3)	9	1996-2000	75	17	40	11	7
Natural Gas											
1950	192 (29.6)	190 (29)	2	0							
1955	231 (23.8)	227 (23.6)	4 (40)	0		1951-55	80	77	4	0	
1960	275 (20.9)	263 (20.7)	12 (24)	0		1956-60	101	92	9	0	
1965	281 (17.0)	251 (16.7)	30 (19)	0		1961-65	80	57	23	0	
1970	301 (13.2)	218 (11.1)	55 (17.8)	28		1966-70	118	53	37	28	
1975	280 (12.7)	174 (10.4)	78 (15)	28		1971-75	91	47	44	0	
1980	266 (12.1)	133 (10.1)	100 (12)	33		1976-80	96	34	56	6	
1985	231 (10.0)	93 (8.6)	103 (9.2)	35 (35)		1981-85	78	20	52	6	
1990	181 (10.1)	60 (10.2)	89 (9.3)	32 (12.8)		1986-90	53	9	38	6	
1995	131 (10.1)	39 (9.1)	67 (10.8)	25 (10.0)		1991-95	28	4	18	6	
2000	87 (10)	24 (9.2)	45 (11.5)	18 (7.2)		1996-2000	11	2	3	6	

*Reserve/production ratio indicated in parentheses.

TABLE B-22 OIL & NGL ADDITIONS TO RESERVES FROM NEW DISCOVERIES (NUCLEAR ELECTRIC ECONOMY)

Period	Total Additions* (10^9 Bbl)	Cumulative from 1970	Additions Onshore (10^9 Bbl)	Cumulative from 1970	Additions Offshore (10^9 Bbl)	Cumulative from 1970	Additions North Slope (10^9 Bbl)	Cumulative from 1970
1951-55	18.4		17.3		1.1		0	
1956-60	16.7		15.5		1.3		0	
1961-65	15.6		13.3		2.4		0	
1966-70	28.0		13.3		4.6		10.2	
1971-75	19.1	19.1	12.4	12.4	6.7	6.7	0	0
1976-80	20.0	39.1	9.8	22.2	8.2	14.9	2	2
1981-85	19.6	58.7	8.2	30.4	9.5	24.4	2	4
1986-90	18.4	77.1	7.1	37.5	9.3	33.7	2	6
1991-95	15.8	92.9	5.5	43.0	8.4	42.1	2	8
1996-2000	12.4	105.3	3.1	46.1	7.3	49.4	2	10

1974 ESTIMATES OF UNDISCOVERED RECOVERABLE OIL & NGL [Gillette-74]

	Total (10^9 Bbl)	Onshore (10^9 Bbl)	Offshore (10^9 Bbl)	Alaska (10^9 Bbl)
USGS	200-400	110-220	64-130	25-50
Mobil	88	13	54	21

*Excluding additions from old wells.

TABLE B-23 NATURAL GAS ADDITIONS TO RESERVES FROM NEW DISCOVERIES (NUCLEAR ELECTRIC ECONOMY)

Period	Total Additions (10^{12} cu ft)	Cumulative from 1970	Additions Onshore (10^{12} cu ft)	Cumulative from 1970	Additions Offshore (10^{12} cu ft)	Cumulative from 1970	Additions North Slope (10^{12} cu ft)	Cumulative from 1970
1951-55	78		74		4		0	
1956-60	98		89		9		0	
1961-65	77		55		22		0	
1966-70	114		51		36		27	
1971-75	88	88	45	45	43	43	0	0
1976-80	93	181	33	78	54	97	6	6
1981-85	75	256	19	97	50	147	6	12
1986-90	51	307	9	106	37	184	6	18
1991-95	27	334	4	110	17	201	6	24
1996-2000	11	345	2	112	3	204	6	30

1974 ESTIMATES OF UNDISCOVERED RECOVERABLE NATURAL GAS [Gillette-74]

	Total (10^{12} cu ft)	Onshore (10^{12} cu ft)	Offshore (10^{12} cu ft)	Alaska (10^{12} cu ft)
USGS	1000-2000	500-1000	395-790	105-210
Mobil	443	65	274	104

TABLE B-24 DRILLING RIG REQUIREMENTS TO PROVIDE OIL AND NATURAL GAS (NUCLEAR ELECTRIC ECONOMY)

Period	Average Number of Active Rigs Total	Avg. Active Rigs Onshore	Avg. Active Rigs Offshore	Avg. Active Rigs North Slope	New Onshore Rigs	New Offshore Rigs
1956-60	1914	1860	54	0		
1961-65	1554	1470	84	0	560	44
1966-70	1157	1030	121	6	480	57
1971-75	1550	1360	180	6	640	95
1976-80	1520	1240	270	6	460	130
1981-85	1650	1220	420	6	580	220
1986-90	1740	1170	560	6	520	240
1991-95	1880	1180	690	6	560	260
1996-2000	1460	680	770	6	0	230

TABLE B-25 MANPOWER, CAPITAL, AND STEEL REQUIREMENTS TO PROVIDE OIL AND NATURAL GAS (NUCLEAR ELECTRIC ECONOMY)

Year	Total Manpower[a]	Total Engineers[b]	Exploration and Development Capital (10^6 '72 $)[c]	5-Year Period	5-Year Total Exp. & Dev. Capital (10^6 '72 $)	5-Year Total of New Steel (10^6 Tons)[d]	5-Year Total of Cement (10^6 Tons)[d]
1950	451,000						
1955	533,000						
1960	486,000						
1965	435,000						
1970	424,000	26,000	5,460				
1975	416,000	29,800	6,700	1971-75	30,400	40	12
1980	425,000	29,600	8,100	1976-80	37,000	39	11
1985	432,000	28,600	8,820	1981-85	42,300	39	11
1990	418,000	26,300	9,510	1986-90	45,800	37	11
1995	400,000	23,700	9,900	1991-95	48,500	36	10
2000	420,000	22,600	8,590	1996-2000	46,200	27	8

a) Total manpower employed in crude petroleum and natural gas extraction and petroleum refining. Source for 1950 through 1970: [DOL-72].

b) Total engineers employed in exploration, production, refining, and research for oil and gas. Source for 1970 (estimate based on 1967 data): [NPC-69].

c) Total direct expenditures for oil and gas exploration and development (omitting all overhead and taxes). Source for 1970: [SPRD-73].

d) Obtained by aggregating unit requirements as described in Appendix B-1-3.

States oil and gas resources that are largely independent of which scenario is actually followed in the future. The impacts are divided into environmental, technological, economic, and social-political categories. The categorization is arbitrary, for every impact has many ramifications in other categories.

Environmental Impacts

This paragraph is concerned with environmental impacts of exploration for and production and refining of petroleum. The many large environmental impacts involved in transporting oil and gas are discussed in Appendix D.

Exploration for onshore, offshore, and North Slope oil and gas means more holes being drilled. This increases the likelihood of ground water and seawater contamination by petroleum; it increases pollution due to disposal of the waste products from exploration; in particular, on the North Slope the disruption of an ecology more fragile than that onshore or offshore is possible. In response to these possible negative impacts, the oil and gas industry is pursuing manpower training programs in order to minimize the pollution caused by human error and is developing technological methods to decrease the probability of blowouts, ruptures, and leaks from offshore drilling. [Shell-72]. An environmental difficulty that probably cannot be met by technical development is the fact that the large oil reserves off the western coast of North America lie in a zone of many faults with a relatively large probability of earthquakes.

Increased recovery from existing oil and gas wells is an alternative to exploration as a way to increase petroleum supplies. Methods of secondary and tertiary recovery involve the potential environmental hazards of pollution by the pressurizing or mixing agents used and loss of unreclaimable water used for flooding. If fracturing is done by nuclear explosions there is some risk of radioactive contamination of groundwater and the rest of the environment, but in any such activity the AEC would presumably be involved from the outset, so existing regulations would apply. Nevertheless nuclear stimulation would almost certainly produce a long vociferous debate between gas industry proponents and their environmentally oriented critics.

Production of oil and gas has positive as well as negative environmental impacts. On the one hand, more oil produced means more oil used which means more pollution from disposed waste and the products of combustion. On the other hand, oil and gas are often substitutable for coal, and air pollution from oil and gas burning is a lesser problem than pollution from burning coal. Production of petroleum also involves an aesthetic problem: an offshore oil derrick visible from the shore is presently considered a visual pollutant.

There is some increase in pollution to be expected from the planned increase in refineries but the increase in pollution will probably not be in proportion to the increase in refinery capacity. Newer refineries are less polluting than older versions, especially in the regard to water usage.

Technological and Scientific Impacts

The technological and scientific impacts discussed in this paragraph cut

both ways: on the one hand they make possible more efficient exploration and production; on the other hand, the petroleum industry itself is the stimulus for many of the developments, developments which impact outside the industry.

Increasing exploration onshore increases knowledge of United States mineral resources, and, because drilling is deeper, adds to geophysical knowledge. Furthermore, this deeper drilling may help to locate geothermal sites which can themselves provide energy. Exploration offshore and in Alaska has the same effects, but in these areas the increase in knowledge is even more significant because comparatively little is known of the ocean floor and Alaskan resource base. There is some possibility that the information obtained from exploration of federal offshore leases will be a bit less proprietary in the future [Tulsa World-74]. Development of offshore petroleum will eventually require more undersea and sea floor operations therby introducing and enhancing technological developments which will make possible many other undersea activities unrelated to petroleum. Similarly, development of North Slope oil and gas reserves spurs the introduction of cold-weather technology adaptable to other Arctic - and perhaps Antarctic - uses.

The need for increased recovery from existing fields stimulates the development of new fracturing technology that may well transfer to the geothermal energy if the "hot rock" processes work out. (See Appendix B-4. OTHER SOURCES)

Economic Impacts

The most obvious economic impact of oil and gas development is the large capital outlay required. Equally obvious is the fact that without this capital outlay the United States will buy oil abroad or do without. The present trends are to develop domestic petroleum and to reduce the reliance on it by conservation measures, thus reducing - though probably not eliminating - the country's dependence on imports.

Development of domestic petroleum supplies requires exploration. This means that rigs and offshore platforms are needed in increasing numbers, which involves shifts in manufacturing capability, capital, manpower, and steel from other uses. Steel in particular is a problem, and the petroleum exploration industry is in competition with many other users for this steel. This will push the price up and perhaps lead to imports of steel, thus to some extent hurting the balance of payments problem that development of domestic petroleum is supposed to help.

Another economic problem of sorts is the existence of bottlenecks in the production of petroleum (See Figures B-2 and B-3). An important component of these bottlenecks is rig manufacturing capability. While this is only a short term problem for onshore rigs (because the manufacturing techniques are used for many other items) it is a long term problem for offshore rigs because the manufacturing techniques are more specialized and because obtaining the large quantity of steel needed is likely to continue to be a problem.

The amount of land and water given over to petroleum exploration, production, and refining is also an economic impact. Water committed to shale oil develop-

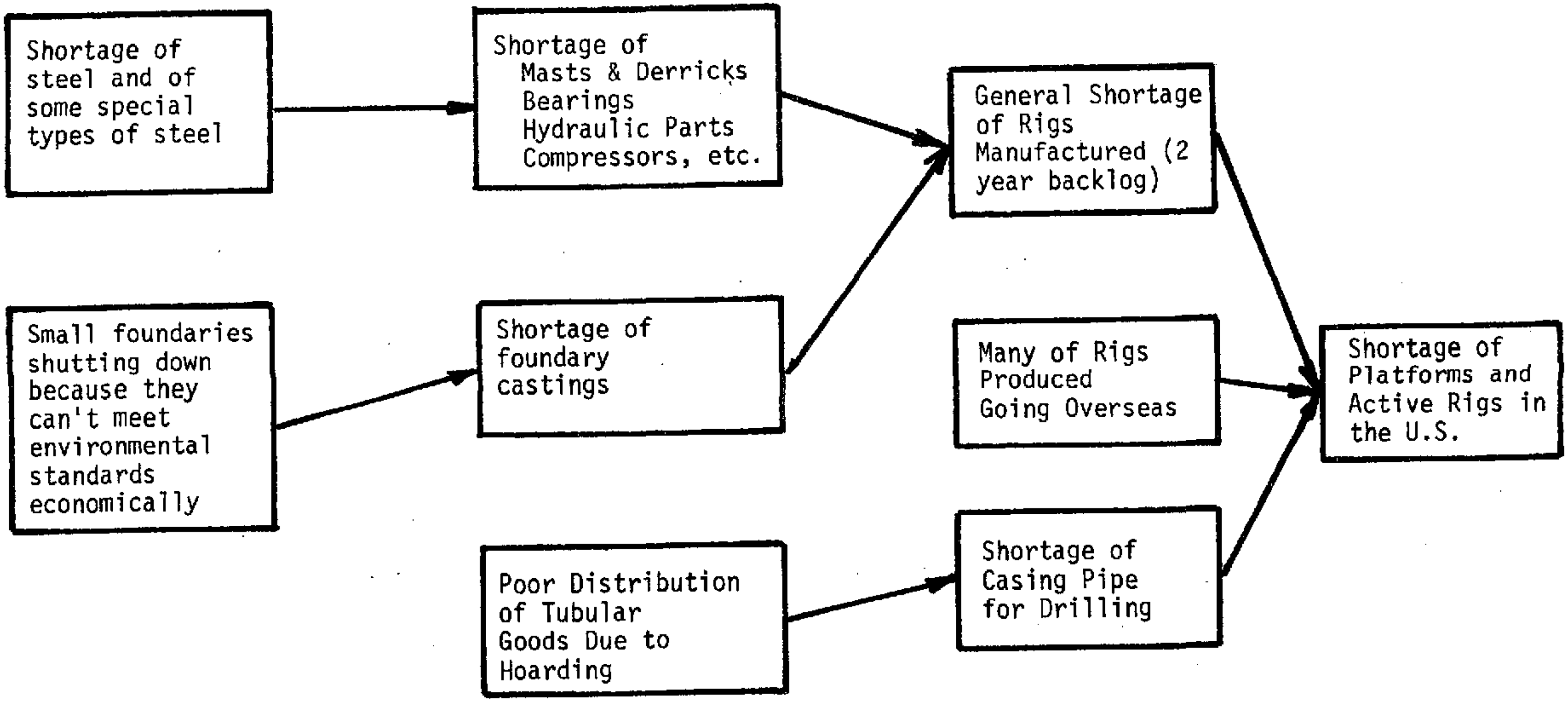

FIGURE B-2 GENESIS OF THE U.S. SHORTAGE OF ACTIVE DRILLING RIGS (COMPOSED FROM OGJ-74-4)

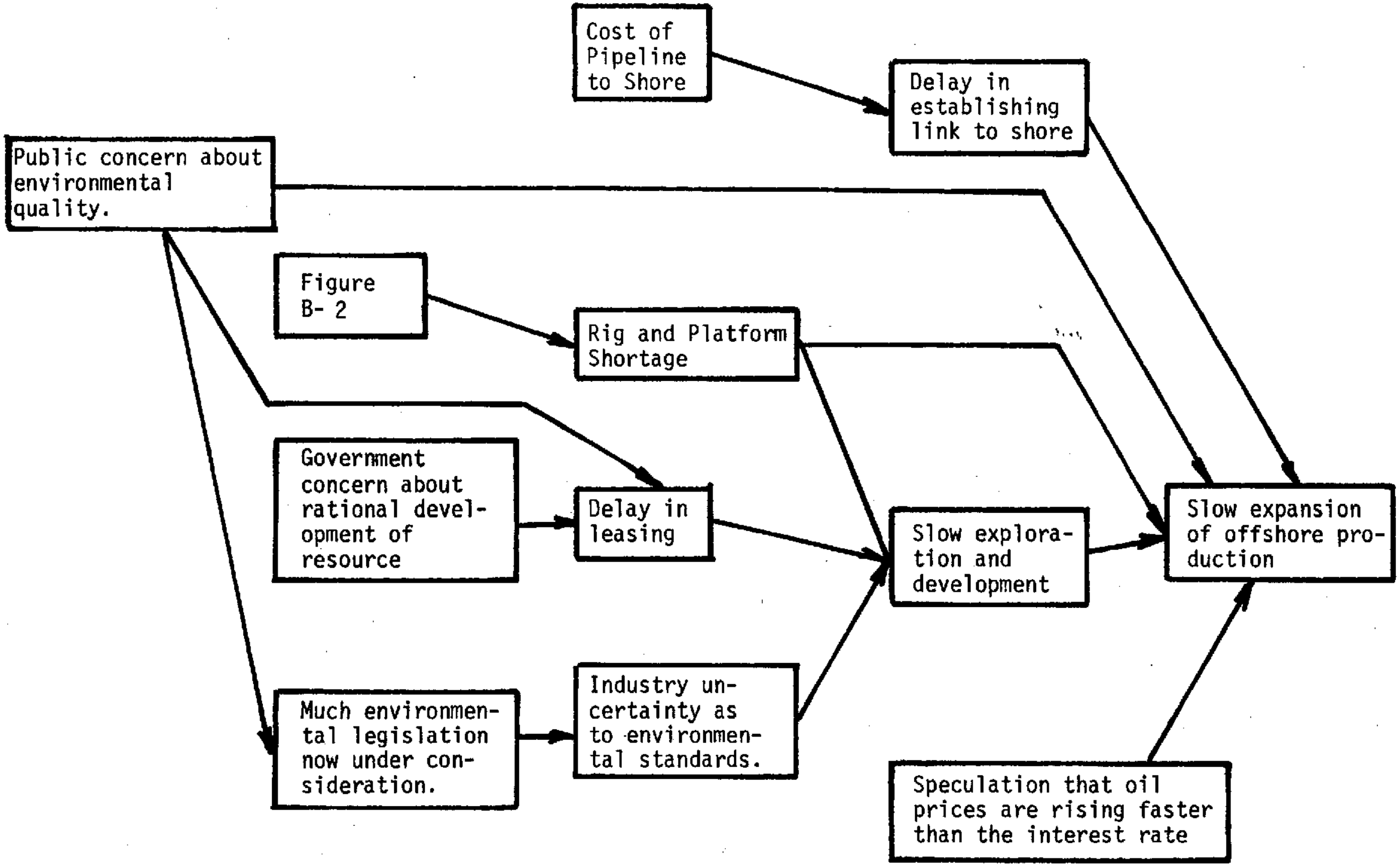

FIGURE B-3 SOURCE OF DELAY IN DEVELOPMENT OF OFFSHORE OIL

ment (Appendix B-4) or to secondary recovery schemes is not available for other use by cities and industries. Land used for exploration or production often has other uses, too. Especially, the western coastal lands with their large oil reserves are valuable both financially and socially as recreational areas, while other areas have agricultural uses.

Social-Political Impacts

A major social and political impact of oil and gas utilization is the amount of land and water used, as discussed above. This means that rational development of petroleum resources needs to be part of a comprehensive land use policy. "Rational development of petroleum resources" also means that all the likely sites should not be drilled up at once, resulting in too rapid depletion of an exhaustible resource. Recognition of these facts is the basis for the offshore leasing program of the Department of the Interior, and is, in part, the basis for oil companies themselves maintaining (or trying to maintain) a reasonable Reserves/Production ratio.

Since petroleum is an exhaustible resource, even if it is found in abundance in the future the twenty first century economy will be largely based on non-fossil energy sources. These sources - fission, fusion, and solar - produce energy in the form of electricity. This means that United States society will make a transition from a style of living predicated on traditional fossil sources to a style of living based on electricity. Development of oil and gas is essential in order to provide some energy during the transition, but it must be recognized that this does divert capital that could be used in the introduction of these other sources. More importantly, perhaps, continued availability of oil and gas may retard the necessary changes in style of living, making gradual transition to a predominantly electric economy more difficult. Here, in fact, is a major continuing opportunity for government intervention to help in this transition by encouraging the development of non-fossil fuel sources.

A rather different social impact of oil and gas development is that relatively few people are required to produce petroleum and that they form a very heterogeneous group. Thus, the industry is less prone to manpower problems. This should be contrasted with the coal industry, where a twenty percent drop in man-hours worked means about a twenty percent drop in coal production.

There are also social impacts of oil and gas development that are much more local in scope. Alaskan society will surely be strained by the influx of people and money associated with petroleum production. There will be a general upward pressure on wages and prices. Communities will face sudden increases in demands for services, and will have to plan for the eventual decline in their economic base as production or exploration tapers off. This illustrates the growing importance of doing more in the way of planning for future contingencies, even at the local level.

Finally, relations between the United States and Canada may be affected by the Alaskan gas: whether a pipeline through Canada will help or hurt these relations is an open question.

B-2 COAL

B-2-1 INTRODUCTION

Coal is widespread and fairly abundant in the United States and the rest of the world. Coal-bearing rocks lie under about 13 percent of the land area of the 50 states and are present in varying amounts in parts of 37 states. The ready availability of coal has been one of the factors responsible for the economic growth and industrial development of this country.

U.S. coal resources are larger than the combined resources of petroleum, natural gas, oil shale, and bituminous sandstone, but coal usage is less than of petroleum and natural gas. These fuels are cleaner and easier to handle than coal. Nevertheless, annual coal production in the United States ranges between 500 and 600 million tons per year (MTPY). Coal exports to Japan, Canada, and Europe are about 10 percent of the annual production.

About 60 percent of the coal consumed is for electrical power production, 20 percent for the steel industry, 18 percent for the manufacturing industry, and 2 percent for all other purposes.

The remaining coal resources of the United States as of January 1, 1972, were estimated to be 3,224,372 million tons (MT). The total estimated coal includes 1,580,987 MT, or 49 percent, which has been identified by mapping and exploration. The remaining 1,643,385 MT has been estimated by geophysical extrapolation of data from identified resources. A similar result is found by assuming that the unknown coal is about equal to the known coal. The estimate of hypothetical or unknown coal is conservative from a geological point of view. The distribution of this coal by states with more than 10 billion short tons (BT) is given in Table B-26 [D.A. Probst and W.P. Pratt-73]. The identified reserves lie in the overburden from the surface to a depth of 3,000 feet. The hypothetical reserves are separated into this overburden and the overburden extending from a depth of 3,000 feet to a depth of 6,000 feet. It is of interest to note that 99.4 percent of the total coal reserves are located in 22 states. The same percentage applies to the identified reserves. If the gushing optimism of the U.S. Geological Survey in their estimations of unknown oil reserves was applied to unknown coal reserves, the total estimated reserves would range from 4,000 to 5,000 billion short tons [Gillette-74].

Identified coal reserves are separated into bituminous, sub-bituminous, lignite, and anthracite coals in Table B-27. The energy in one pound of bituminous coal varies from 12,000 to 15,000 BTU, from 9,000 to 11,000 BTU in one pound of sub-bituminous coal, from 6,000 to 7,000 BTU in one pound of lignite, and about 15,000 BTU in one pound of anthracite. Although the heating value of bituminous coal is higher than that of the sub-bituminous coal, this advantage is offset by the higher sulfur content in the bituminous coal [D.A. Probst and W.P. Pratt-73]. The percentage of sulfur and pyritic sulfur (in iron pyrite or "fool's gold") is highest in bituminous coals of Pennsylvania age in the Appalachian and Interior coal basins. It is relatively low in the sub-bituminous coal and lignite of the Rocky Mountain and Northern Great Plains areas.

TABLE B-26 TOTAL ESTIMATED COAL RESERVES OF THE UNITED STATES, JANUARY 1, 1972, BY STATES WITH MORE THAN 10 BILLION SHORT TONS

State	Identified Reserves	Hypothetical Reserves Overburden		Total Reserves
		0-3000 ft	3000-6000 ft	
	In Millions of Short Tons			
Alabama	15,342	20,000	6,000	41,342
Alaska	130,081	130,000	5,000	265,081
Arizona	21,246	0	0	21,246
Colorado	80,581	146,000	145,000	371,581
Illinois	139,124	100,000	0	239,124
Indiana	34,573	22,000	0	56,573
Iowa	6,509	14,000	0	20,509
Kansas	18,674	4,000	0	22,674
Kentucky	64,842	52,000	0	116,842
Missouri	31,014	18,200	0	49,214
Montana	221,675	157,000	0	378,675
New Mexico	61,427	27,000	21,000	109,427
North Dakota	350,630	180,000	0	530,630
Ohio	41,358	2,000	0	43,358
Oklahoma	3,281	20,000	10,000	33,281
Pennsylvania	77,269	10,000	0	87,269
Texas	12,872	14,000	0	26,872
Utah	23,721	21,000	35,000	79,721
Virginia	9,687	5,000	100	14,787
Washington	6,179	30,000	15,000	51,179
West Virginia	100,628	0	0	100,628
Wyoming	120,656	325,000	100,000	545,656
Other States	9,618	9,080	5	18,703
United States	1,580,987	1,306,280	337,105	3,224,372

TABLE B-27 IDENTIFIED COAL RESERVES OF THE UNITED STATES, JANUARY 1, 1972, BY STATE

In Millions Of Short Tons

State	Bituminous Coal	Sub-Bituminous Coal	Lignite	Anthracite and Semi-Anthracite	Total
Alabama	13,342				15,342
Alaska	19,413	110,668	2,000		130,081
Arizona	21,246				21,246
Arkansas	1,638		350	430	2,418
Colorado	62,339	18,242		78	80,659
Illinois	139,124				139,124
Indiana	34,573				34,573
Iowa	6,509				6,509
Kansas	18,674				18,674
Kentucky	64,842				64,842
Maryland	1,158				1,158
Missouri	31,014				31,014
Montana	2,299	131,855	87,521		221,675
New Mexico	10,752	50,671		4	61,427
North Dakota			350,630		350,630
Ohio	41,358				41,358
Oklahoma	3,281				3,281
Pennsylvania	56,759			20,510	77,269
South Dakota			2,031		2,031
Tennessee	2,572				2,572
Texas	6,048		6,824		12,872
Utah	23,541	180			23,721
Virginia	9,352			335	9,687
Washington	1,867	4,190	117	5	6,179
West Virginia	100,628				100,628
Wyoming	12,705	107,951			120,656
Other States	999	316	46		1,361
United States	686,033	424,073	449,519	21,362	1,580,987

Another arrangement of the distribution of identified coal reserves is given in Table B-28, where 17 states, each with more than 10 BT, have 89.5 percent of the U.S. identified coal reserves. The states are grouped by geographical regions or provinces. Alaska is not included because of distance and mining limitations. The Northern Great Plains Province, which includes North Dakota and Montana, has more than 36 precent of the total reserve coal in these two states. Most of the coal in the Northern Great Plains is lignite. The Rocky Mountain Province, with about 20 percent of the coal reserves, contains bituminous and sub-bituminous coals. Most of the coal in the Eastern province, with 19 percent of the coal reserves, and the Interior province, with 15 percent, is bituminous. These are shown in Figure B-4.

When the limitation is 50 BT, only 9 states are left in Table B-29, with 77 percent of the U.S. coal reserves. Table B-29 represents the major sources of the coal required by the FTFB, AFTF and NEE scenarios.

B-2-2 PRODUCTION, LABOR, AND CAPITAL COSTS

The coal required for the FTFB, AFTF and NEE scenarios is given in Tables B-30 and B-31. Coal requirements are divided into direct use, coal gasification, and coal liquefaction. These are expressed in quadrillion BTU (quads) and in millions of tons of coal per year (MTPY). The NEE coal requirement is 2.14 times greater than the other two, reflecting a laissez faire attitude toward a rapid rate of consuming our dwindling fossile energy resources. The slower growth rates for FTFB and AFTF indicate more awareness of the need for conservation and consciousness of our resources. The conversion between BTU and tons of coal is taken to be 12,000 BTU per pound [National Coal Association-74].

Production of bituminous coal and lignite in the United States from 1955 to 1972 [U.S. Bureau of Mines-55 to 72] is given for strip mines in Table B-32. Nonperiodic intervals provide a more realistic picture of production because the cyclical influence is removed. The years selected are 1955, 1960, 1965, 1969 and 1972. Coal produced by underground mines for the same periods for the same years is given in Table B-33. The coal production from strip mines has more than doubled with a continuous increase, while coal produced by underground mines has gradually, but not uniformly, decreased. The greatest expansion in strip mining has occurred in the Rocky Mountain Province, followed by the Northern Great Plains Province. Anthracite, mined predominantly in Pennsylvania, is not included here because it is a very low percentage of the total coal produced. It is also expected to remain constant in output during our next 25 years of rapid expansion of energy consumption.

The numbers of strip and underground mines for the time periods covered above are presented in Table B-34. The increase of strip mines and the decrease of underground mines are the results of greater productivity of strip miners, about three to one, the low sulfur in strip mined coal, and fewer safety regulations. [Probst and Pratt-73].

Table B-35 presents some typical manpower requirements for strip mines in West Virginia, Kentucky, Oklahoma, Arizona, Colorado, Montana, and North Dakota [Bureau of Mines-72]. The number of workers are divided into production, main-

TABLE B-28 IDENTIFIED COAL RESERVES OF THE UNITED STATES, JANUARY 1, 1972, BY STATES WITH MORE THAN 10 BILLION SHORT TONS

State	Bituminous Coal	Sub-Bituminous Coal	Lignite	Total
	In Millions of Short Tons			
Eastern Province				
Alabama	13,342		2,000	15,342
Kentucky	64,842			64,842
Ohio	41,358			41,358
Pennsylvania	56,759 (and 20,510 Anthracite)			77,269
West Virginia	100,628			100,628
	297,439			299,439
Interior Province				
Illinois	139,124			139,124
Indiana	34,573			34,573
Kansas	18,674			18,674
Missouri	31,014			31,014
Texas	6,048		6,824	12,872
	229,433			236,257
Northern Great Plains Province				
Montana	2,299	131,855	87,521	221,675
N. Dakota			350,630	350,630
			438,151	572,305
Rocky Mountain Province				
Arizona	21,246			21,246
Colorado	62,339	18,242		80,581
New Mexico	10,752	50,671		61,423
Utah	23,541	180		23,721
Wyoming	12,705	107,951		120,656
	130,583	177,044		307,627
Other States	47,641	115,174	2,544	165,359
U.S. Total	707,395	424,073	449,519	1,580,987

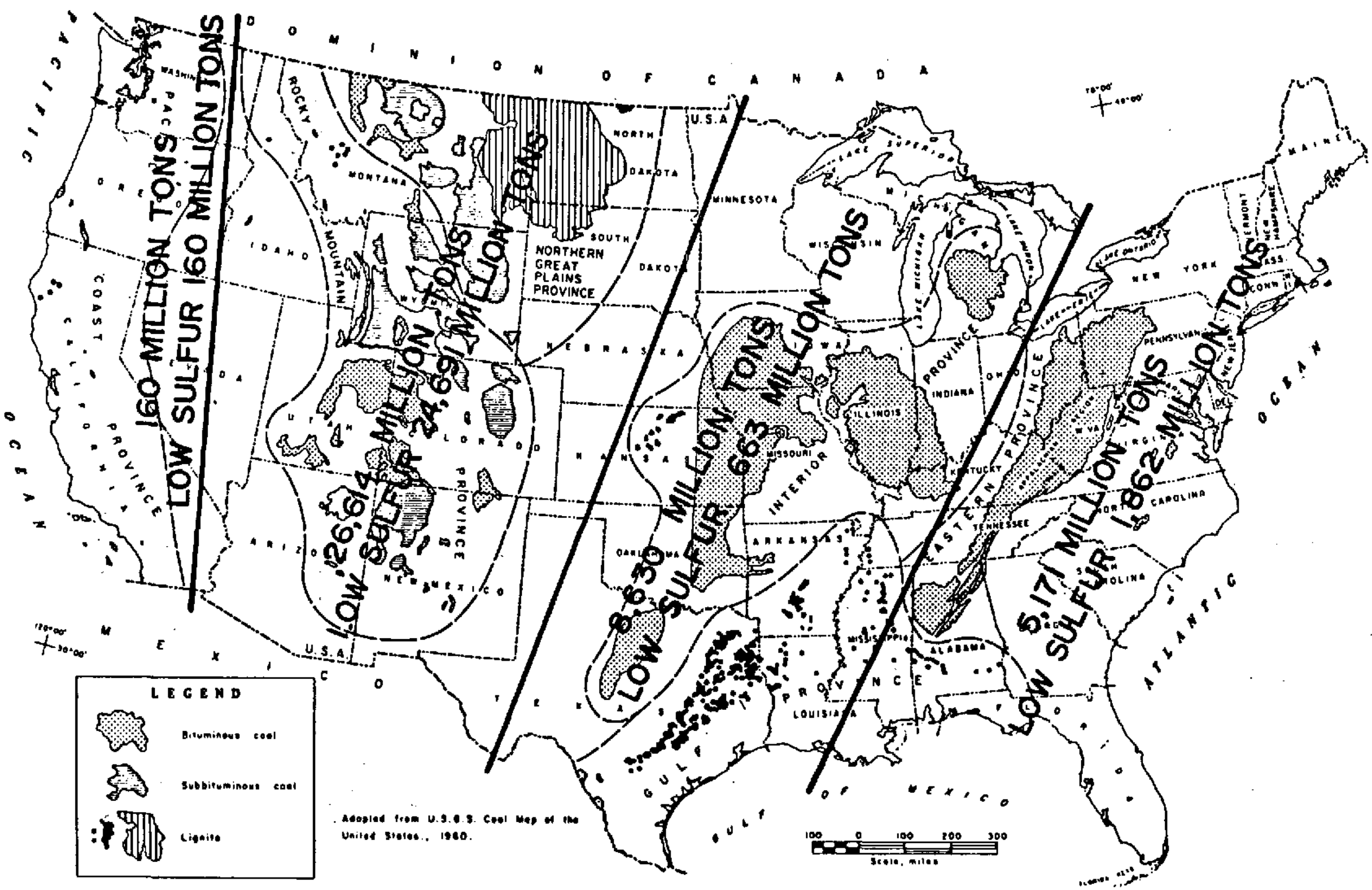

FIGURE B-4 STRIP MINEABLE COAL RESERVES IN THE UNITED STATES [Probst and Pratt-72]

TABLE B-29 IDENTIFIED COAL RESERVES OF THE UNITED STATES, JANUARY 1, 1972, BY STATES WITH MORE THAN 50 BILLION SHORT TONS

State	Bituminous	Sub-Bituminous	Lignite	Total
		In Millions of Short Tons		
Eastern Province				
Kentucky	64,842			
Pennsylvania	77,269 (Includes 20,510 Anthracite)			
West Virginia	100,628			
	242,739			242,739
Interior Province				
Illinois	139,124			139,124
Northern Great Plains Province				
Montana	2,299	131,855	87,521	
North Dakota			350,630	
			438,151	572,305
Rocky Mountain Province				
Colorado	62,339	18,242		
New Mexico	10,752	50,671		
Wyoming	12,705	107,951		
	85,796	176,864		262,660
Other States	237,437	115,354	11,368	364,159
U.S. Total	707,395	424,073	449,519	1,580,987

TABLE B-30 COAL REQUIREMENTS FOR NEE AND FTFB
NUCLEAR ELECTRIC ECONOMY IN QUADRILLION
BTU's PER YEAR

	1972	1975	1980	1985	1990	1995	2000
Direct Use	12.4	17	25	32	34	36	39
Gasification	--	--	--	2	6	10	14
Liquefaction	--	--	--	--	4	8	13
Total	12.4	17	25	34	44	54	66
IN MILLIONS OF TONS PER YEAR (MTPY)							
	517	708	1042	1417	1833	2250	2750

FORD TECHNICAL FIX - BASE CASE IN QUADRILLION BTU's PER YEAR

	1972	1975	1980	1985	1990	1995	2000
Direct Use	12.4	13.9	15.2	18.4	20	22.3	24.8
Gasification	--	--					
Liquefaction	--	--	1.2	2	2.7	4	6
Total	12.4	13.9	16.4	20.4	22.7	26.3	30.8
IN MILLIONS OF TONS PER YEAR (MTPY)							
	517	579	683	850	946	1096	1283

These figures are based on 12000 Btu in one pound of coal.

TABLE B-31 COAL REQUIREMENTS

ALTERNATE TO FORD TECHNICAL FIX
IN QUADRILLION BTU's PER YEAR

	1972	1975	1980	1985	1990	1995	2000
Direct Use	12.4		17.2	21.2	24	24.8	24.8
Gasification	--	--	--	--	--	--	--
Liquefaction	--	--	1.0	2.1	3.4	4.7	6.0
Total	12.4	13.9	18.2	23.3	27.4	29.5	30.8

IN MILLIONS OF TONS PER YEAR (MTPY)

	1972	1975	1980	1985	1990	1995	2000
	517	579	812	971	1182	1229	1283

These figures are based on 12000 BTU in one pound of coal.

TABLE B-32 BITUMINOUS COAL AND LIGNITE PRODUCTION IN THE UNITED STATES FROM 1955 to 1972, BY PROVINCES IN MILLIONS OF SHORT TONS PER YEAR (MTPY) FROM STRIP MINES

Location	1955	1960	1965	1969	1972
Eastern Province					
Alabama	2.111	2.558	4.809	8.130	13.177
Kentucky	13.643	19.672	30.143	37.503	55.776
Maryland	.237	.488	.737	.962	1.435
Ohio	23.958	23.883	26.365	31.014	34.077
Pennsylvania	20.518	20.876	23.767	21.970	26.264
Tennessee	1.635	1.764	2.067	3.371	5.113
Virginia	.982	1.371	3.081	3.561	7.935
West Virginia	9.379	6.754	10.462	14.464	19.101
	72.463	77.366	101.431	120.975	162.878
Interior Province					
Illinois	18.676	22.671	32.670	34.640	33.802
Indiana	11.181	10.785	13.210	13.534	24.503
Kansas	.727	.885	1.310	1.313	1.227
Missouri	3.075	2.802	5.538	3.299	4.551
Oklahoma	1.469	1.094	.964	1.713	2.536
Texas	--	--	--	--	4.045
	35.128	38.237	51.692	54.499	70.664
Northern Great Plains Province (Lignite in North Dakota)					
Montana	.808	.197	.300	.995	8.204
North Dakota	3.081	2.523	2.713	4.704	6.632
	4.697	2.720	3.013	5.699	14.836
Rocky Mountain Province					
Arizona	--	--	--	--	2.954
Colorado	.357	.693	1.270	1.915	2.452
New Mexico	--	--	2.778	3.636	7.235
Washington	--	--	--	--	2.606
Wyoming	1.539	1.713	3.136	7.899	10.487
	1.896	2.406	7.184	13.450	25.734
Other States	.909	1.901	1.920	2.400	1.618
United States	115.093	122.630	165.240	197.023	275.730

TABLE B-33 BITUMINOUS COAL AND LIGNITE PRODUCTION IN THE UNITED STATES FROM 1955 TO 1972, BY PROVINCES IN MILLIONS OF SHORT TONS PER YEAR (MTPY) FROM UNDERGROUND MINES

Location	1955	1960	1965	1969	1972
Eastern Province					
Alabama	10.971	10.365	9.946	9.287	7.588
Kentucky	54.440	44.469	49.633	64.336	56.494
Ohio	12.632	9.206	11.827	18.625	16.269
Pennsylvania	64.904	44.071	56.016	56.039	49.133
Tennessee	5.341	3.939	3.547	4.473	5.866
Virginia	22.241	25.820	28.872	30.373	23.993
West Virginia	126.589	109.210	134.629	121.623	101,662
	297.118	247.080	294.470	304.756	261.005
Interior Province					
Illinois	27.257	23.307	25.813	30.082	31.721
Indiana	4.967	4.753	2.355	.368	1.446
	32.224	28.060	28.168	30.450	33.167
Rocky Mountain Province					
Colorado	3.211	2.914	3.520	3.615	3.070
New Mexico	.174	.250	.434	.836	1.014
Utah	6.295	4.955	4.992	4.657	4.770
	9.680	8.119	8.946	9.108	8.854
Other States	4.443	5.110	1.077	2.817	1.077
United States	343.465	284.888	332.661	347.131	304.103

TABLE B-34 UNDERGROUND AND STRIP BITUMINOUS COAL AND LIGNITE MINES IN THE UNITED STATES FROM 1955 TO 1972 BY PROVINCES

U = Underground S = Strip

Location	1955		1960		1965		1969		1972	
Eastern Province	U	S	U	S	U	S	U	S	U	S
Alabama	195	39	135	39	143	58	74	64	24	101
Kentucky	1,852	118	1,630	129	1,594	116	1,028	163	697	517
Maryland		26		37		35	20	31		41
Ohio	233	259	149	265	93	264	44	312	35	236
Pennsylvania	797	585	680	553	494	581	228	541	159	622
Tennessee	409	87	332	71	180	41	112	62	108	94
Virginia	1,007	31	1,201	35	1,153	56	598	76	327	244
W. Virginia	996	168	1,479	140	1,353	191	867	229	548	288
	5,489	1,313	5,606	1,269	5,010	1,342	2,971	1,478	1,898	2,143
Interior Province										
Illinois	103	68	59	69	41	49	28	37	26	33
Indiana	44	55	34	47	20	41	3	11	4	36
Kansas		19		11		6		4		4
Missouri		28		23		13		8		11
Oklahoma		21		15		11		7		13
Texas										3
	147	191	93	165	61	120	31	67	30	100

TABLE B-34 (CONT) UNDERGROUND AND STRIP BITUMINOUS COAL AND LIGNITE MINES IN THE UNITED STATES FROM 1955 TO 1972 BY PROVINCES
(Concluded)

Location	1955 U	1955 S	1960 U	1960 S	1965 U	1965 S	1969 U	1969 S	1972 U	1972 S
North Great Plains Province										
Montana		5		5		3		5		6
North Dakota		28		31		28		20		14
		33		36		31		25		20
Rocky Mountain Province										
Arizona										1
Colorado	110	7	87	7	72	7	43	9	27	8
N. Mexico	28		18		5	3	4	3	1	4
Utah	50		45		31		21		21	
Washington										2
Wyoming		8		9		9				13
	188	15	150	16	108	19	68	12	49	28
United States	5,824	1,552	5,849	1,486	5,179	1,512	3,070	1,582	1,977	2,291

TABLE B-35 MANPOWER AND LABOR COSTS FOR
STRIP MINES IN THE UNITED STATES

Personnel	Number	Daily Wage	Annual
1 MTPY - West Virginia - Bituminous			
Production	39	$40.32	$ 436,068
Maintenance	22	38.94	272,604
Supervision	18		222,000
	79		$ 930,672
3 MTPY - West Virginia - Bituminous			
Production	69	$39.24	$ 696,000
Maintenance	38	38.94	355,128
Supervision	28		360,000
	135		$1,411,128
1 MTPY - Western Kentucky - Bituminous			
Production	40	$42.24	$ 405,156
Maintenance	23	38.60	213,084
Supervision	15		187,200
	78		$ 805,440
1 MTYP - Western Kentucky - Bituminous			
Production	36	$39.86	$ 333,636
Maintenance	23	36.98	213,084
Supervision	15		189,600
	74		$ 736,320
3 MTPY - Western Kentucky - Bituminous			
Production	68	$39.88	$ 683,928
Maintenance	29	38.20	268,272
Supervision	15		189,600
	112		$1,114,180

TABLE B-35 (CONT) MANPOWER AND LABOR COSTS FOR STRIP MINES IN THE UNITED STATES (Continued)

Personnel	Number	Daily Wage	Annual
1 MTPY - Oklahoma - Bituminous			
Production	57	$40.26	$ 718,680
Maintenance	18	38.93	168,120
Supervision	18		238,800
	93		$1,125,600
1 MTPY - Arizona, Colorado, New Mexico, or Utah - Sub bituminous			
Production	29	$40.96	$ 351,132
Maintenance	11	38.59	110,292
Supervision	9		134,400
	49		$ 595,824
5 MTPY - Arizona, Colorado, New Nexico, or Utah - Sub bituminous			
Production	74	$41.05	$ 940,668
Maintenance	32	38.59	312,840
Supervision	17		219,600
	123		$1,473,108
5 MTPY - Montana - Sub bituminous			
Production and Maintenance	84	$35.21	$ 735,720
Supervision	11		166,800
	95		$ 902,520
5 MTPY - Wyoming - Sub bituminous			
Production and Maintenance	84	$40.86	$ 854,160
Supervision	11		166,800
	95		$1,020,960
1 MTPY - North Dakota or Wyoming - Lignite			
Production	27	$39.62	$ 332,400
Maintenance	11	38.93	110,292
Supervision	9		134,400
	47		$ 577,092

Personnel	Number	Daily Wage	Annual
5 MTPY - North Dakota or Wyoming - Lignite			
Production	53	$40.99	$ 654,744
Maintenance	22	38.57	217,032
Supervision	14		188,400
	89		$1,060,176

tenance, and supervision for 1, 3, and 5 MTPY strip mines. Supervision numbers include engineers, office workers, and foremen. Daily wages for an eight hour day are given for production and maintenance workers. The total annual labor costs cover each category of work.

Similar descriptions are given for a typical 2 MTPY underground mine in Table B-36 [S. Katell and E.L. Hemingway-74]. The larger number of workers can be compared with Table B-35 for strip mines.

Some of the equipment costs for strip mines are given in Table B-37 [Bureau of Mines-72]. Locations and mine capacities are presented for draglines, drills for overburden, and shovels. The price for steel for moving and fabricated equipment is roughly a dollar per pound. This was obtained from the Bucyrus-Erie Company's equipment specification lists and discussions with their staff members.

From the information given in preceding Tables and references, cost analyses for strip mines [Bureau of Mines-72] and underground mines [S. Katell and E. Hemingway-74] are given in Table B-38. The mine sizes selected are used in the future requirements for the FTFB, AFTF, and NEE scenarios in the next section. Based on a current discounted cash flow of 20 percent, coal prices vary from \$3.45 to \$10.14 per ton at the mine. The transportation costs, at about 0.6 cents per ton mile, would increase the price of Western coal over that of Eastern coal. These prices are based on 1973 data, and price increments added by distributors. Steel requirements are also given. These costs compare closely with those from the Pittsburg and Midway Coal Company.

B-2-3 FUTURE COAL REQUIREMENTS

The coal requirements for the FTFB appear in Table B-39. The depletions for strip mines in the West include the Rocky Mountain and Northern Great Plains Provinces, while those in the East include the Eastern and Interior Provinces. Those for the underground mines in the East cover the Eastern and Interior Provinces. Depletion is predicated on a thirty year life for existing mines and on a twenty year life for new and replacement mines. The replacement of depleted mines is done in the same proportions as the current type of production. The current production is about equally divided between strip and underground mines at about 300 MTPY for each. With the strip mines, about 240 MTPY come from Western surface mines and 60 MTPY come from Eastern surface mines. With a depletion of 20 MTPY, the depleted mines must be replaced by underground mines having 10 MTPY capacity and by strip mines having 10 MTPY capacity. New replacement underground mines are in the East, and those for surface mines are replaced with 8 MTPY in the East and 2 MTPY in the West.

Increases in consumption require an expansion of mines to a production level of 1283 MTPY. This requires new mines with capacities of 766 MTPY and replacements of depleted mines with capacities of 686 MTPY. Depleted mines will be replaced in accord with the program in the previous paragraph. New strip mines will be expanded ninefold, while underground mines will be increased by 180 percent. The reasoning here is that Western coals run in thick horizontal seams near the surface and are low in sulfur. They are also cheaper and non-caking. The division

TABLE B-36 PERSONNEL AND LABOR COST
FOR A 2 MTPY UNDERGROUND
BITUMINOUS MINE

Personnel	Total	Daily Wages	Annual Cost 220 Days
Underground			
Continuous miner operator	27	$50.00	$300,960
Loading machine operator	27	47.25	284,625
Machine operator helper	27	47.25	284,625
Shuttle car operator	54	43.25	521,730
Roof bolter	54	47.25	569,250
Bratticeman	27	42.75	257,895
Utility man	27	44.75	269,775
Section mechanic	27	50.00	300,960
	270		$2,789,820
Supply motorman	6	43.25	57,970
Beltman	18	42.75	171,930
Trackman	9	42.75	85,965
Wireman	9	42.75	85,965
Precision mason	12	44.75	119,900
Pumper	3	42.75	28,655
Utility crew	18	44.75	179,850
Roving mechanic	9	50.00	100,820
	84		$830,555
Outside			
Lampman, shop mechanics	15		$158,620
Salary			
Supervisors and office	56		719,200
Total	425		$4,498,200

TABLE B-37 OVERBURDEN DRILLS, SHOVELS, AND DRAGLINES FOR STRIP MINES IN COST AND CAPACITY

Mine Output in MTPY	Location	Drills Size in Inches	Cost	Shovels Capacity in cu yds	Cost	Draglines Capacity in cu yds	Cost
1	West Virginia	9-12	$250,000	65	$ 5,500,000		
3	West Virginia	12-15(2)	610,000	160	15,000,000		
1	Kentucky	15	308,600	65	5,500,000	20	$ 1,400,000
1	Kentucky	15	308,600			32	2,757,000
3	Kentucky	15(2)	617,200	130	9,775,000	60	4,830,000
1	Oklahoma	7-9(2)	253,600	40(2)	8,400,000		
1	Rocky Mountains	15	356,000			35	2,350,000
5	Rocky Mountains	15(2)	712,000			65(3)	15,000,000
5	Montana	12-15(4)	596,000			65	5,782,000
5	Wyoming	12-15(4)	596,000			65	5,782,000
1	North Dakota					21	1,400,000
5	North Dakota					65	10,000,000

TABLE B-38 SUMMARY OF COST ANALYSES

Strip Mines		
Estimated capital investment	$ 15,998,000.00	$ 28,656,700.00
Per ton of coal	16.00	5.73
Operating cost per year	5,267,000.00	12,030,800.00
Per ton of coal	5.27	2.40
Selling price, 20 percent discounted cash flow	8.08	3.45
Underground		
Estimated capital investment	$ 21,850,700.00	$ 35,705,900.00
Per ton of coal	21.85	17.85
Operating cost per year	7,793,900.00	13,830,300.00
Per ton of coal	7.79	6.92
Selling price, 20 percent discounted cash flow	10.14	8.95

Steel Necessary in the Above Mines

1 MTPY Strip	5,400 Tons
5 MTPY Strip	9,500 Tons
1 MTPY Underground	2,900 Tons
2 MTPY Underground	4,700 Tons

TABLE B-39 COAL REQUIREMENTS BY CATEGORY IN MTPY FOR THE FORD TECHNICAL FIX

Year	Depletions			Increase in Consumption			Total Required				Total All Mines
	Strip		Underground	Strip		Underground	Strip			Underground	
	West	East	East	West	Interior	East	West	Interior	East	East	
1973	2	8	10	10	2	7	12	2	8	17	39
4	2	8	10	10	2	7	12	2	8	17	39
1975	2	8	10	15	2	7	17	2	8	17	44
6	2	8	10	10	2	7	12	2	8	17	39
7	2	8	10	10	2	7	12	2	8	17	39
8	2	8	10	10	2	8	12	2	8	18	40
9	2	8	10	10	2	8	12	2	8	18	40
1980	2	8	10	15	3	8	17	3	8	18	46
1	2	8	10	15	3	8	17	3	8	21	49
2	2	8	10	15	4	8	17	4	8	21	50
3	2	8	10	20	4	12	22	4	8	22	56
4	2	8	10	20	4	12	22	4	8	22	56
1985	2	8	10	20	4	12	22	4	8	22	56
6	2	8	10	10	1	6	12	1	8	16	37
7	2	8	10	10	2	6	12	2	8	16	38
8	2	8	10	10	2	6	12	2	8	16	38
9	2	8	10	10	2	7	12	2	8	17	39
1990	2	8	10	15	2	7	17	2	8	17	44
1	2	8	10	15	3	10	17	3	8	20	48
2	2	8	10	15	3	10	17	3	8	20	48
3	12	10	17	15	4	10	27	4	10	27	68
4	12	10	17	15	4	11	27	4	10	28	69
1995	17	10	17	20	4	11	37	4	10	28	79
6	12	10	17	20	3	12	32	3	10	29	74
7	12	10	17	20	3	13	32	3	10	30	75
8	12	10	18	20	4	13	32	4	10	31	77
9	12	10	18	20	4	13	32	4	10	31	77
2000	17	11	18	25	4	13	42	4	11	31	88

between Western Provinces and the Interior Province is about five to one.

Table B-40 describes the NEE coal requirements. Replacement mines follow the same format as that for the FTFB. New mines must be increased twenty-five-fold for strip mining, and underground mines increased by the threefold.

The Table B-41 is similar to Table B-39. Slight differences occur in the rates of coal consumption. The AFTF and FTFB are preferred because they provide future energy for future generations.

In all three Tables, the depletions increase in 1993 because the new mines added in 1973 are depleted.

Table B-42 contains the number of people necessary for 5 and 1 MTPY strip mines and for 1 and 2 MTPY underground mines. The number of these mines are also included. A different picture in Table B-43 shows the actual population in mining work every year for AFTF, FTFB, and NEE. Table B-43 differs from Table B-42 in the following format. Table B-43 has the actual population of miners, while Table B-42 has the number of new miners needed to satisfy each scenario. The NEE scenario will have twice as many "black lung" patients as either of the other scenarios. Forests and countryside will be desecrated twice as fast with NEE.

The supervisory and engineering populations appear in Table B-44, while the working miners (non-sup and non-engr) appear in Table B-45.

The capitalization and steel necessary for the three scenarios appear in Table B-46. Five year sums are included.

Coal gasification is not included in the coal requirements in terms of mines, labor, or capitalization. Details are shown in Table B-47. The last Table, B-48, indicates the high requirements of NEE. By the year 2000, the NEE program will consume 315 million gallons of water per year. With the effects of droughts evident in many parts of our nation, the removal of water from agricultural crops and from water supplies will create conflicts. Does the average consumer want "throw away beer bottles" or aluminum beer cans if the energy requirements removes the water necessary to make the beer?

TABLE B-40 COAL REQUIREMENTS BY CATEGORY IN MTPY FOR THE NUCLEAR ELECTRIC ECONOMY

Year	Depletions Strip West	Depletions Strip East	Depletions Underground East	Increase in Consumption Strip West	Increase in Consumption Strip Interior	Increase in Consumption Underground East	Total Required Strip West	Total Required Strip Interior	Total Required Strip East	Total Required Underground East	Total All Mines
1973	2	8	10	35	6	20	37	6	8	30	81
4	2	8	10	35	6	21	37	6	8	31	82
1975	2	8	10	40	7	21	42	7	8	31	88
6	2	8	10	35	7	21	37	7	8	31	83
7	2	8	10	35	7	21	37	7	8	31	83
8	2	8	10	40	7	22	42	7	8	32	89
9	2	8	10	40	7	22	42	7	8	32	89
1980	2	8	10	40	8	22	42	9	8	32	90
1	2	8	10	40	9	24	42	9	8	34	93
2	2	8	10	40	9	24	42	9	8	34	93
3	2	8	10	40	9	24	42	9	8	34	93
4	2	8	10	45	9	24	47	9	8	34	98
1985	2	8	10	45	9	24	47	9	8	34	98
6	2	8	10	45	9	26	47	9	8	36	100
7	2	8	10	45	9	27	47	9	8	37	101
8	2	8	10	45	9	27	47	9	8	37	101
9	2	8	10	50	10	27	52	10	8	37	107
1990	2	8	10	50	10	27	52	10	8	37	107
1	2	8	10	45	9	26	47	9	8	36	100
2	2	8	10	45	9	27	47	9	8	37	101
3	37	14	30	45	10	27	82	10	14	57	163
4	37	14	31	50	10	27	87	10	14	58	169
1995	42	15	31	50	10	27	92	10	15	58	175
6	37	15	31	55	11	32	92	11	15	63	181
7	37	15	31	55	11	32	92	11	15	63	181
8	42	15	32	55	12	32	97	12	15	64	188
9	42	15	32	55	12	33	97	12	15	65	189
2000	42	16	32	60	12	33	102	12	16	65	195

TABLE B-41 COAL REQUIREMENTS BY CATEGORY IN MTPY FOR THE AFTF

Year	Depletions			Increase in Consumption			Total Required				Total
	Strip		Underground	Strip		Underground	Strip			Underground	All
	West	East	East	West	Interior	East	West	Interior	East	East	Mines
1973	2	8	10	10	2	7	12	2	8	17	39
4	2	8	10	10	2	7	12	2	8	17	39
1975	2	8	10	15	2	7	17	2	8	17	44
6	2	8	10	25	5	15	27	5	8	25	65
7	2	8	10	25	5	15	27	5	8	25	65
8	2	8	10	25	5	15	27	5	8	25	65
9	2	8	10	25	5	16	27	5	8	26	66
1980	2	8	10	30	6	16	32	6	8	26	72
1	2	8	10	15	4	10	17	4	8	20	49
2	2	8	10	15	4	11	17	4	8	21	50
3	2	8	10	15	4	11	17	4	8	21	50
4	2	8	10	20	4	11	22	4	8	21	55
1985	2	8	10	20	4	11	22	4	8	21	55
6	2	8	10	20	4	14	22	4	8	24	58
7	2	8	10	20	5	14	22	5	8	24	59
8	2	8	10	25	5	14	27	5	8	24	64
9	2	8	10	25	5	14	27	5	8	25	65
1990	2	8	10	25	5	15	27	5	8	25	65
1	2	8	10	5	1	3	7	1	8	13	29
2	2	8	10	5	1	3	7	1	8	13	29
3	12	10	17	5	1	3	17	1	10	20	48
4	12	10	17	5	1	3	17	1	10	20	48
1995	17	10	17	5	2	4	22	2	10	21	55
6	27	13	25	5	1	3	32	1	13	28	74
7	27	13	25	5	1	3	32	1	13	28	74
8	27	13	25	5	1	4	32	1	13	29	75
9	27	13	26	5	1	4	32	1	13	30	76
2000	32	14	26	10	2	4	42	2	14	30	92

TABLE B-42 LABOR REQUIRED FOR COAL MINING INCREASES

	Ford Technical Fix					Alternate Ford Fix					Nuclear Electric				
	Strip		Underground			Strip		Underground			Strip		Underground		
	5 MT	1 MT	2 MT	1 MT	Annual	5 MT	1 MT	2 MT	1 MT	Annual	5 MT	1 MT	2 MT	1 MT	Annual
1972															
1973	2	12	6	5	4,959	2	12	6	5	4,959	7	16	10	10	8,805
4	2	12	6	5	4,959	2	12	6	5	4,959	7	16	10	11	9,048
1975	3	12	6	5	5,082	3	12	6	5	5,082	8	17	10	11	9,250
6	2	12	6	5	4,959	5	15	8	9	7,387	7	17	10	11	9,127
7	2	12	6	5	4,959	5	15	8	9	7,387	7	17	10	11	9,127
8	2	12	6	6	5,202	5	15	8	9	7,387	8	17	11	10	9,432
9	2	12	6	6	5,202	5	15	9	8	7,569	8	17	11	10	9,432
1980	3	14	6	6	5,483	6	16	9	8	7,771	8	18	11	10	9,511
1	3	14	7	7	6,151	3	14	7	6	5,908	8	19	11	12	10,076
2	3	14	7	7	6,151	3	14	7	7	6,151	8	19	11	12	10,076
3	4	14	7	8	6,517	3	14	7	7	6,151	8	19	11	12	10,076
4	4	14	7	8	6,517	4	14	7	7	6,274	9	19	11	12	10,199
1985	4	14	7	8	6,517	4	14	7	7	6,274	9	19	11	12	10,199
6	2	12	5	6	4,777	4	14	8	8	6,942	9	19	12	12	10,624
7	2	12	5	6	4,777	4	15	8	8	7,021	9	19	12	13	10,867
8	2	12	5	6	4,777	5	15	8	8	7,144	9	19	12	13	10,867
9	2	12	6	5	4,959	5	15	8	9	7,387	10	20	12	13	11,069
1990	3	12	6	5	5,082	5	15	8	9	7,387	10	20	12	13	11,069
1	3	14	7	6	5,908	1	11	4	3	3,421	9	19	12	12	10,624
2	3	14	7	6	5,908	1	11	4	3	3,421	9	19	12	13	10,867
3	5	16	9	9	7,891	3	13	7	6	5,829	16	26	19	19	16,714
4	5	16	9	10	8,134	3	13	7	6	5,829	17	26	19	20	17,080
1995	7	16	9	10	8,380	4	14	7	7	6,274	18	27	19	20	17,282
6	6	16	10	9	8,439	6	16	9	10	8,257	18	28	21	21	18,454
7	6	16	10	10	8,682	6	16	9	10	8,257	18	28	21	21	18,454
8	6	16	10	11	8,925	6	16	10	9	8,439	20	29	21	22	19,022
9	6	16	10	11	8,925	6	16	10	10	8,682	20	29	22	21	19,204
2000	8	18	10	11	9,329	7	18	10	10	8,963	20	30	22	21	19,283

In strip mines, there are 79 and 123 people in 1 and 5 MT mines; and in underground mines, 243 and 425 people in 1 and 2 MT mines.

*Includes manpower for coal gasification plants in the west.

TABLE B-43 LABOR POPULATION ENGAGED IN COAL MINING FOR THE THREE SCENARIOS

	Ford Technical Fix		Alternate Ford Tech		Nuclear Energy Economy	
	Increase Per Year	Total	Increase Per Year	Total	Increase* Per Year	Total [a]
1972		149,265		149,265		149,265
3	1,922	151,187	1,922	151,187	5,498	154,763
4	1,922	153,109	1,922	153,109	5,741	160,504
1975	2,045	155,154	2,045	155,154	5,943	166,447
6	1,922	157,076	4,350	159,504	5,820	172,267
7	1,922	158,998	4,350	163,854	5,820	178,087
8	2,165	161,163	4,350	168,204	6,125	184,212
9	2,165	163,328	4,532	172,736	6,125	190,337
1980	2,446	165,774	4,734	177,470	6,204	196,541
1	3,114	168,888	2,871	180,341	6,400	202,941
2	3,114	172,002	3,114	183,455	6,400	209,341
3	3,480	175,482	3,114	186,569	6,400	215,741
4	3,480	178,962	3,237	189,806	6,523	222,264
1985	3,480	182,442	3,237	193,043	6,523	228,787
6	1,740	184,182	3,905	196,948	6,456	235,243
7	1,740	185,922	3,984	200,932	6,699	241,942
8	1,740	187,662	4,107	205,039	6,699	248,641
9	1,902	189,564	4,350	209,389	6,876	255,517
1990	2,045	191,609	4,350	213,739	6,876	262,393
1	2,871	194,480	384	214,123	6,456	268,849
2	2,871	197,351	384	214,507	6,699	275,548
3	2,952	200,303	870	215,377	7,048	282,596
4	3,195	203,498	870	216,247	7,171	298,767
1995	3,298	206,796	1,192	217,439	7,171	296,938
6	3,480	210,276	870	218,309	8,466	305,404
7	3,723	213,999	870	219,179	8,466	313,870
8	3,723	217,722	1,052	220,231	8,729	322,599
9	3,723	221,445	1,113	221,344	8,911	331,510
2000	3,846	225,291	1,192	222,536	8,990	340,500

a) Does not include manpower for coal gasification mines.

TABLE B-44 SUPERVISORY AND ENGINEERING POPULATIONS IN COAL MINING SCENARIOS

	Ford Technical Fix	Alternate Ford Technical Fix	Nuclear Electric Economy
1972	14,926	14,926	14,926
1975	15,515	15,515	16,645
1980	16,577	17,747	19,654
1985	18,244	19,304	22,879
1990	19,161	21,374	26,239
1995	20,680	21,744	29,694
2000	22,529	22,254	34,050

not include coal gasification manpower.

TABLE B-45 NON-SUPERVISORY AND NON-ENGINEERING POPULATIONS IN COAL MINING SCENARIOS

	Ford Technical Fix	Alternate Ford Technical Fix	Nuclear Electric Economy[a]
1972	134,339	134,339	134,339
1975	139,639	139,639	149,802
1980	149,197	159,723	176,887
1985	164,198	173,739	205,908
1990	172,448	192,365	236,154
1995	186,116	195,695	267,244
2000	202,762	200,282	306,450

a) Does not include coal gasification manpower.

TABLE B-46 CAPITALIZATION AND STEEL REQUIRED FOR COAL MINES

Capital in Millions of Dollars and Steel in Thousand of Tons

	Ford Technical Fix				Alternate Ford Fix				Nuclear Electric Economy			
	Capital		Steel		Capital		Steel		Capital		Steel	
1973	$573		126		$573		126		$1032		227	
4	573		126		573		126		1054		230	
1975	601	$1746	135	386	601	$1746	135	386	1098	$3184	244	701
6	573		126		865		190		1070		236	
7	573		126		865		190		1070		236	
8	623		128		865		190		1113		246	
9	623		128		879		192		1113		246	
1980	684	3075	148	656	924	3475	207	971	1128	5492	252	1216
1	741		156		691		153		1102		234	
2	741		156		713		156		1102		234	
3	792		168		713		156		1102		234	
4	792		168		741		165		1131		244	
1985	792	3858	168	816	741	3599	165	951	1131	5566	244	1119
6	587		124		799		173		1051		210	
7	587		124		815		178		1073		185	
8	587		124		844		188		1073		185	
9	601		126		865		190		1118		228	
1990	630	2994	135	631	865		190	920	1118	5434	228	1036
1	720		148		413		96		1051		210	
2	720		148		413		96		1073		213	
3	946		195		675		148		1767		366	
4	968		198		675		148		1817		377	
1995	1025	4377	217	905	742	2917	165	653	1862	7571	394	1562
6	1010		209		968		213		1971		411	
7	1032		212		968		213		1971		411	
8	1054		215		981		215		2066		438	
9	1054		215		1003		217		2080		440	
2000	1143	6317	244	1095	1064	4984	238	1095	2116	10205	446	2146

TABLE B-47 COAL GASIFICATION REDUCES STRIP MINES FROM DIRECT USE--
OR REQUIRES 5 MTPY STRIP MINES SHOWN BELOW

	Mines	Miners	Capital	Steel
1981	3	369	$ 86,100,100	28,500 Tons
1982	3	"	"	"
1983	3	"	"	"
1984	3	"	"	"
1985	3	369	86,100,000	28,500 Tons
1986	7	861	200,900,000	66,500 Tons
1987	7	"	"	"
1988	7	"	"	"
1989	7	"	"	"
1990	7	"	"	"
1991	7	"	"	"
1992	7	"	"	"
1993	7	"	"	"
1994	7	"	"	"
1995	7	"	"	"
1996	7	"	"	"
1997	7	"	"	"
1998	7	"	"	"
1999	7	"	"	"
2000	7	861	200,900,000	66,500 Tons

TABLE B-48 ADDITIONAL POWER AND WATER REQUIREMENTS FOR UNDERGROUND COAL MINES

Power in 10^8 KWh Per Year

	Ford Tech	Alt Ford	Nuclear
1973	3.08	3.08	5.48
1975	3.08	3.08	5.68
1980	3.43	4.89	5.82
1985	4.04	3.84	6.23
1990	3.08	4.59	6.78
1995	5.14	3.84	8.62
2000	5.68	5.48	11.85

Water in 10^8 Gallons Per Year

	Ford Tech	Alt Ford	Nuclear
1973	1.53	1.53	2.70
1975	1.53	1.53	2.79
1980	1.62	2.34	2.88
1985	1.98	1.89	2.88
1990	1.53	2.25	3.33
1995	2.52	1.89	5.22
2000	2.79	2.70	5.85

A 1 MTPY mine uses 20.26 million kilowatt hours per year and 9.24 million gallons of water per year, while a 2 MTPY mine uses 34.5 kilowatt hours and 17.8 million gallons.

B-2-4 IMPACTS OF SCENARIO REQUIREMENTS FOR COAL

A large impact on the U.S. economy is the NEE scenario requirement for coal. In 1972, the coal consumption was 517 MTPY. It rose to 556 MTPY in 1973, and is projected at a 7 percent rise in 1974 to 595 MTPY. The NEE requirement is 2750 MTPY in the year 2000, an increase of 4.62 times the 1974 consumption. The AFTF and FTFB scenarios both reach 1283 MTPY, an increase of 2.16 times the 1974 consumption in the year 2000.

Political Impacts

About half of the U.S. coal output already comes from strip mines, and energy companies have taken leases on large chunks of the vast unexploited coal reserves in Wyoming, North Dakota, and Montana, where low sulfur coal is located fairly close to the surface. With about 1,000 ground-up acres added each week to the existing 2,500,000 acres of strip mined land, Congress is taking measures to make sure that Appalachia does not occur again in Wyoming or North Dakota.

Late in July, 1974, the House of Representatives passed a compromise bill [Time - 74] that would set a new agency to regulate strip mining, 291 to 81. It went to a House - Senate conference committee to mesh with a tougher Senate bill. The bill will require restoration of strip mined land to its original contour.

Federal standards for "regrading and revegetating" of stripped land and preservation of water tables will not affect Pennsylvania and the Midwest, where stricter state laws and adequate rainfalls assure compliance. The impact is on low-rainfall states in the west, such as Montana, the Dakotas, New Mexico, and Wyoming, where 25 billion tons of coal reserves are located. Reclamation is impossible or difficult at best. An added problem is a high demand for Western coal, whose low sulfur makes it attractive to industries who would otherwise invest in expensive antipollution equipment to conform with another Federal law, the Clean Air Act of 1970.

A reflection from Carl Bagge of the National Coal Association is more dismal. He calls the House bill a disaster, claiming that it brings mining to a stop in many Western areas.

Other political impacts are the persistence of mine disasters and "black lung" disease that led to the Coal Mine Health and Safety Act of 1969 [Ford Foundation - 1974]. Measures for safer mining resulted in slower mining. A sharp drop in underground coal mine productivity followed implementation of new safety procedures [National Coal Association - 1972]. Many small mines closed because the costs of safety equipment exceded the prices received for coal. The sulfur oxide standards in the Clean Air Act of 1970 reduced the use of coal as an industrial and electric power fuel.

Environmental Impacts

The increased consumption of coal will have environmental impacts in several areas. Restrictions on strip mining in Western states, described above, will shift demands to underground and strip mines in Eastern states such as West

Virginia, Pennsylvania, Kentucky, and Ohio. The costs of mining in the East are much higher than those in the West. A second hurdle is the higher sulfur content in Eastern coal. In order to meet the increased demands for coal in all three scenarios, the sulfur dioxide and other pollutant levels must be relaxed or waived, or as an alternative, the strip mining bill, described above, will have to permit waivers or exceptions. The choice will be between visits to Eye, Ear, Nose and Throat specialists or an adjustment to the scenery seen. Most conservation and environmental organizations are opposed to strip mining unless there is suitable restoration.

Comparisons between strip and underground mines can be made in labor productivity. A 5 MTPY strip mine employs 123 people. A 1 MTPY underground mine employs 243 people. The strip mine worker produces 40,650 tons per year, and the underground mine worker produces 4,115 tons per year.

Trace element pollution increases with the increased consumption of coal as a fuel. Several trace elements, lead, antimony, zinc, mercury, arsenic, cadmium, and nickel appear to be associated with the inorganic sulfur in coal [C.E. Capes - 1974], so that health hazards are greater for high sulfur coal. Beryllium and selenium generally come in highest concentrations with Appalachian coals, and in lowest concentrations in Western coal.

Another problem of high-sulfur coal is acid mine drainage, where sulfuric acid leached from exposed coal seams in both underground and strip mines will contaminate surface and ground water. A Department of the Interior estimate in 1969 undicated that the costs for abatement and control of acid mine drainage would be $6.6 billion [Appalachian Regional Commission - 1969]. Stack gas sulfur dispersal may require very high stacks.

Economic Impacts

Important in a short term increase in coal production are the coal miners. They mine the coal. Long-standing grievances over working conditions lead to local work stoppages and slowdowns. Recent years found coal mines operating 225 working days a year, equivalent to a 4.5 day working week. Production increases would be possible if labor disputes could be settled on a more permanent basis. A 5 day working week would increase coal production by 70 million tons per year. This leads to a subtle problem. A bitter prolonged strike would seriously delay reaching the coal output required by the FTFB or AFTF scenarios. The NEE scenario would be out of reach.

New mines, especially strip mines, are another method for increasing coal production. Strip mining in 1973 produced 275 million tons of coal [National coal Association - 1974]. It produced 244 million tons of coal in 1970, in contrast with underground mines, which produced 339 million tons in 1970 and 301 million tons in 1973. Short term increases can be made from small mines in Appalachia and in the Midwest (like Illinois) with existing equipment. Draglines, manufactured by Bucyrus-Erie and Marion, are requiring a three to four year delivery date.

New underground mines take about five years to put into operation. However, no mine will be initiated unless a purchaser commits himself to a long term contract, usually for the 20 year life of the mine. Unresolved air pollution problems, strip mine contour and foliage restoration, and mine safety and respiratory

problems make purchasers reluctant to enter into long-term contracts.

Other economic factors include a current shortage of underground miners and mining engineers. Even assuming labor tranquility and harmony, the disappearance of mining engineering from college curricula and the difficulty of mining as an occupation allow only a gradual expansion of mining production under optimal conditions.

About 50 percent of all coal moves by rail, frequently in 10,000 ton unit trains, and often over distances less than 500 miles. Another 20 percent moves to market through inland waterways and in combinations of rail and barge. Some Eastern mine-mouth power plants send energy by high voltage transmission lines. Moving Western coal to markets 1,000 miles or more depends upon economic. Costs rise linearly with distance when the market is more than 500 miles away. Unit trains move coal at 0.6 cents per ton mile, and at 1,000 miles or more, this cost becomes $6.00 or more per ton.

Technical Impacts

Liquid fuel was commercially made from coal in Germany between 1930 and 1945. The most recent liquefaction plant in South Africa has been operating successfully for more than 15 years. It is part of all three scenarios. The NEE scenario commences with coal liquefaction in 1990 and increases linearly to 13 quads or 542 MTPY in the year 2000. This is almost our present coal production level. The FTFB starts in 1980 somewhat linearly to 6 quads or 250 MTPY in the year 2000. The AFTF is similar to the FTFB scenario. The latter scenarios have a more gradual rise in coal-based liquid fuel than in the NEE case. The rates are 54 MTPY per year and 12 MTPY per year, respectively. It is felt that rapid expansion in the NEE case can cause premature commercial production which could lead to excessively high prices. The cost of investing too heavily now in an immature technology will be tomorrow's burden.

The Bucyrus-Erie Company will complete a new facility in Pocatello, Idaho, in about two years. This facility will reduce the drag time on draglines, make more shovels, and shovel-out related items.

Social Impacts

The dominant social impact of coal production is the degradation of land and water resources in the immediate vicinities. The influx of strip miners into sparsely settled Western hamlets will be accompanied by higher demands for limited services and by upward pressures on prices and wages. As one local general store operator said, "Some of these miners are my best friends, but I don't want my daughter to marry one of them."

With underground mines, local hospitals will have to treat with respiratory ailments and related cardiovascular ailments. In both types of mines, a major consideration for the miner is the increased cost of relocating in a new community.

B-3 URANIUM IN THE UNITED STATES

B-3-1 INTRODUCTION

Uranium used for electrical generation in nuclear power plants is obtained by the mining and milling of uranium bearing ore. The projected increase in nuclear power will demand a corresponding growth in the existing uranium mining and milling industry. In this discussion of uranium in the United States, the present reserves of and production capability for uranium are presented. Data are given for typical uranium mining and milling operations. These data are used to formulate path requirements for the energy futures selected for analysis in this study. Finally, a discussion is included of the impacts due to the amount of uranium mining and milling needed for these cases.

B-3-2 PRESENT SITUATION

The uranium mining and milling industry has existed in the past primarily for the production of materials for national defense. Before 1948, nearly 12,000 Tons of uranium concentrates were obtained through the Manhattan Project [Appelin-73]. The reserves of high grade uranium ore at that time were estimated to contain 2,200 Tons of U_3O_8. Since 1948, U_3O_8 reserves in high grade ore have grown to approximately 275,000 Tons through 1973. However, these high grade ores do not reflect the true potential for nuclear fuels of the industry. To describe this potential, it is convenient to split the discussion into two parts, namely, evaluation of total reserves and production capability.

<u>Uranium Reserves for Nuclear Power</u>

With the successful development of nuclear power, the Atomic Energy Commission instigated an expanded listing of uranium reserves according to the price per pound required for recovery by existing mining and milling techniques. Table B-49 shows the 1970 estimate of U. S. nuclear fuel resources with increasing price. The amounts of reserves at each price are subject to improvements in mining and milling techniques. Knowledge of fuel reserves over the years has been associated with underestimations and uranium resources are probably not an exception. Since light-water reactors are not as yet producing a substantial amount of electricity, the pressure to find new reserves has not been intense in the past. However, with a substantial increase in nuclear power plants, a great increase in exploration and discovery of uranium ores should occur.

The amount of uranium reserves is assessed by the AEC from the results of exploratory drilling. Since 1969, there has been some upsurge in exploratory activity which has located significant new ore reserves in several of the western United States. Overall, the 120 million feet of exploratory drilling between 1969 and 1972 increased the total reserves of U_3O_8 at \$15/lb. or less from 1.28 million Tons to 1.52 million Tons. As an indication of the cost of drilling activity, the 80 million feet of exploratory drilling in 1973 cost \$105.0 million. Another 23 million feet of development drilling cost \$20.9 million. Finally, \$78 million

TABLE B-49 NUCLEAR FUEL RESOURCES[a]

\$/lb.	U_3O_8 Resources at this or lower price, tons
8	594,000
10	940,000
15	1,450,000
30	2,240,000
50	10,000,000
100	25,000,000

[a]As of (1970) the AEC gives these estimates of the U.S. uranium reserves in deposits known or expected to be found, as a function of uranium price. Source: [Hottel & Howard-73], P. 229.

was spent in 1973 for geological and geophysical investigations, research and supervisory activities connected with exploration efforts.

The AEC maintains detailed accounts of the changes in U. S. uranium ore reserves. Table B-50 is included as an example of the accounting procedure. The entry for depletion by erosion is an estimate of ore losses due to underground mine cave-ins or open-pit mining backfills. The usefulness of this detailed accounting procedure is the close watch it maintains on changes in the reserve picture. For example, the failure to add significant reserves in the $8 and $10/lb. categories, shown by Table B-50, provides data for advanced planning of nuclear fuel costs. Also, these data can show what level of pricing discourages availability of capital for exploration.

If, in the future, vigorous exploration programs must be carried out to maintain or increase ore reserves, the data on which the AEC bases its assessment and accounting of ore reserves will be a valuable aid. The estimates for reserves less than $10/lb. are based primarily on the evaluation of drilling samples. Analysis of the samples yields the dissemination of uranium minerals in sandstone and vein deposits. Potential resources in extensions of known deposits or in known favorable geologic structures are included in the reserves above $10/lb. Identification of additional favorable geologic structures can serve as a guide to a stepped up exploration effort and experience with analysis of drilling samples can expedite the evaluation of actual reserves in all potentially favorable locations.

The reserves in Table B-50 includes only the ores to be mined exclusively for U_3O_8 at a cost below $100/lb. There are tremendous reserves of U_3O_8 in, for example, the Chattanooga shale which exists at mineable depths in Kentucky and neighboring states but which is estimated to yield U_3O_8 at costs exceeding $100/lb, In addition to low-grade ores such as the Chattanooga shale, a well-established source of uranium is as a by-product in the treatment of gold tailings in South Africa [McGinley-73]. The possibility exists to obtain uranium as a by-product from the copper and phosphate industries. Copper leaching solutions contain from 2 to 15 ppm of U_3O_8 which could yield approximately 1000 Tons of U_3O_8 annually [Facer-73]. Central Florida phosphate rock contains enough uranium to yield approximately 1500 to 2000 Tons of U_3O_8 as a by-product. Finally, mine waters contain 2 to 20 ppm U_3O_8 which could yield this U_3O_8 content as a by-product of required mine water treatment. When associated with the breeder reactor, the energy potential available in uranium and thorium is a least a few orders of magnitude greater than that from combining all fossil fuels. [SCI AM-71]

Production Capability for Uranium

Uranium ore is obtained either from underground or open-pit mines with approximately 55 percent currently coming from underground mines. The most productive underground uranium mines are in the Ambrosia Lake Area of New Mexico. Additional mines are located in other areas of New Mexico, Utah, Wyoming and Colorado. An average of about 8 years is needed to acquire land, complete exploration of known deposits and develop the buildings and equipment to begin production in a new mine.

TABLE B-50 CHANGES IN U.S. ORE RESERVES IN 1972[a]

	$8.00		$10.00	
Status	No. of Properties	Tons, U_3O_8	No. of Properties	Tons, U_3O_8
Jan. 1, 1972 Reserve	732	273,213	983	333,484
New Properties	25	8,027	36	16,330
Reevaluation-Additions	80	13,469	84	14,066
Reevaluation-Subtractions	19	(9,038)	23	(12,967)
Depletion-Production	172	(12,482)	176	(13,255)
Depletion-Erosion		0	33	(1,118)
Jan. 1, 1973 Reserve	781	273,189	1,041	336,540

[a][Appelin-73]

The history of U. S. production of uranium is presented in Table B-51. At the end of 1973, there were 20 uranium mills operating or on standby to handle the mine output. The overall mine-mill production capability was approximately 18,000 Tons of U_3O_8 annually.

However, these mining and milling capabilities do not fully reflect the ability of the industry to meet rapidly growing needs in the near future. Although it no longer purchases U_3O_8, the AEC has stockpiled U_3O_8 in the past and has announced its intention to use this accumulated supply to preproduce enriched uranium for future sales [Woodmansee-72]. Moreover, new mines are under development in Canada, Australia and South Africa. The possibility exists for the acquisition of U_3O_8 concentrate from foreign sources in anticipation of the increased demand to fuel the 205 nuclear plants expected to be on-line by the mid-1980's.

B-3-3 UNIT REQUIREMENTS

Uranium ore is obtained from open-pit and underground mines. The Anaconda Mining Company provided details on their open-pit operation in Grants, New Mexico [AMC-74]. These data are presented in Table B-52. The AEC provided data for typical underground mines with an accompanying mill in the Grand Junction, Colorado area. These data are presented in Table B-53.

B-3-4 PATH REQUIREMENTS

The first step in analysis of the path requirements for uranium mining and milling is to determine the amount of uranium which will be needed. Before addressing the specific energy futures selected for this study, it is interesting to look at the predictions of Neef [Neef-73]. These estimates are shown in Table B-54. The most likely values are used in Table B-55 to establish an independent set of estimates for the ore requirements, number of mines and manpower for the future underground mining and milling industry. Table B-53 can be used to derive amounts of other materials.

The U_3O_8 equivalent and number of mines required to produce the nuclear energy postulated in the FTFB, ATTF and NEE are shown in Table B-56. The calculation procedure is indicated in the footnotes. The data of Table B-52 for an open-pit mine are used in these and subsequent calculations. Data in Table B-53 and Table B-55 allow one to adjust numbers, if desired, to include the proper share of underground mine operations. By comparing the forecasts of U_3O_8 tonnages in Tables B-55 and B-56, the FTFB and AFTF uranium requirements are seen to be only slightly lower than the independent estimates from Neef's projection. The NEE case will need much more uranium and this will carry through in all subsequent materials and manpower estimates.

Table B-57 recasts the numbers in Table B-56 to concentrate on the mines and the required ore production rather than the U_3O_8 eventually

TABLE B-51 U.S. PRODUCTION OF URANIUM

Year	U_3O_8, Tons
1950	810
1955	4,400
1960	18,800
1965	10,400
1970	12,800
1975[a]	16,000

[a]Estimated by C. Woodmansee of the U.S.B.M. The figure 14,000 tons was given for 1974.

TABLE B-52 OPERATION REQUIREMENTS OF AN OPEN-PIT URANIUM MINE AND ACCOMPANYING MILL

Output:	2,400 T/day of ore shipped to mill via railroad over distance of 50 miles (at cost of 5¢/Ton mile) 10,000 lb/day of U_3O_8 obtained after milling 300,000 T/month of ore production capability
Equipment:	1 Power Shovel (6 Yard Capacity) 4 Front-End Loaders (15 Yard Capacity each) 5 Front-End Loaders (6 Yard Capacity each) 20 Trucks (20 Ton Capacity Each) 17 Trucks (50 Ton Capacity Each)
Water:	2×10^6 Gal/Day at Mill
Fuel:	6500 Gal/Day #2 Diesel Fuel at Mine
Electricity:	2×10^6 KWH per Month at Mill
Maintenance and Operation: of Mill	\$40,000/Month for Supplies, etc. \$50,000/Month for Labor
Labor:	300 at mill; 350 at mine

TABLE B-53 OPERATION REQUIREMENT OF AN UNDERGROUND MINE AND ACCOMPANYING MILL[a]

Output:	1400 Ton/Day of ore to mill over 5-day week (May be one mine, several mines or part of a mine) 1000 Ton/Day milled over 7-day week	
Mine Life:	15 years	
Equipment and Materials over Mine Life:	Drill Steel (6 1/2')	23,000 each
	Bits	48,000 each
	Dynamite (45 percent)	2,300,000 #
	NCN (Explosive)	6,000,000 #
	Roof Bolts (w/plates)	4,100,000 each
	Mesh (9' Chain link)	1,300,000 Ft.
	Stulls (9', 6', and 5')	1,000,000 each
	Timber Sets	180,000 each
	Lagging	1,200,000 Ft.
	Rail (45")	220,000 Ft.
	Ties	37,000 each
	Spikes	150,000 #
	Pipe (4" and 2")	240,000 Ft.
	Vent Tubing (12")	560,000 Ft.
	Slusher Cable	4,800,000 Ft.
	Hoses	540,000 Ft.
	Gasoline	180,000 Gal.
	Diesel Fuel	350,000 Gal.
	Rock Drill Oil	5,000 Gal.
	Lubricating Oil	10,000 Gal.
	Electricity/Ton of Ore	43 KWh
Equipment and Material for Milling:	Office, mill buildings and ore pad	20 acres
	Tailing Pond	100 acres
	For each ton of Ore Processed:	
	Water	600 Gal.
	Sulfuric Acid	100 #
	Sodium Chlorate	3 #
	Ammonia	2 #
	Sodium Chloride	15 #
	Grinding Steel	1 #
	Flocculants	0.2 #
	Decanol	0.1 #
	Amine	00.8 #
	Electricity	25 KWh
	Natural Gas	400 Cu. Ft.
	Diesel Fuel	0.1 Gal.
	Gasoline	0.2 Gal.
Labor:	167 at mine; 60 at mill	

[a]From AEC - Grand Junction, Colorado Office.

TABLE B-54 TOTAL U.S. URANIUM REQUIREMENTS[a]

(U_3O_8 in short tons)

Calendar Year	United States		
	Most Likely	High	Low
1975	18,200	20,400	15,100
1980	38,400	44,000	36,600
1985	71,500	85,500	59,900
1990	117,900	140,100	87,100
1995	142,600	173,700	100,100
2000	153,600	192,000	110,000

[a] [Neef-73]

TABLE B-55 PROJECTION OF UNDERGROUND PRODUCTION & MANPOWER REQUIREMENTS FOR U_3O_8 - 1974 - 2000[f]

Year	[a]Forecast of needs, U_3O_8 Tons	[b]Forecast of U_3O_8 needed from mines, Tons	[c]Tons of ore from mines (x 10^6 Tons)	[d]Production units, number	[e]Estimated Manpower Needed
1974	13,800	7,590	3.0	12	2,040
1975	18,200	10,010	4.2	16	2,760
1980	38,400	21,120	8.1	31	5,400
1983	55,900	30,845	13.9	53	9,100
1985	71,500	39,325	20.5	79	13,700
1990	117,900	64,845	42.2	162	28,000
1995	142,600	78,430	58.4	225	39,000
2000	153,600	84,480	62.9	242	42,000

[a]Assuming (0.30 percent EPT).

[b]55 percent of the total annual requirements.

[c]Based on expected ore grade and 96 percent mill recovery.

[d]Production unit - 1,000 TPD per 260-day year.

[e]Based on 7 tons per hourly manshift and one salaried employee per five hourly employees.

[f]Modified from data of [Appelin & Waulters-74]

TABLE B-56 PREDICTIONS OF ENERGY REQUIREMENTS & EQUIVALENTS IN U_3O_8

Year	FTFB			AFTF			NEE		
	Mines[a]	Quads	U_3O_8, tons[a]	Mines	Quads	U_3O_8, tons	Mines	Quads	U_3O_8, tons
1975	11	2.8	16,000	10	2.5	14,300	8	2	11,400
1980	29	7.6	43,500	13	3.3	18,900	31	8	45,800
1985	44	11.6	66,400	27	7.0	40,100	61	16	91,600
1990	53	14.0	80,100	41	10.7	61,200	126	33	188,900
1995	62	16.3	93,300	55	14.4	82,400	225	59	337,700
2000	70	18.4	105,300	70	18.4	105,300	359	94	538,100
TOTAL[b]	(Cumulative)		1,780,600			1,327,200			4,968,500

[a]Based on Quads required and that 171 tons of U_3O_8 generates 1000 MW-years of electrical energy in light-water reactors. Also, 1500 tons of U_3O_8 was produced per year from the milling operation for the ore from the strip mine of Anaconda at Grants, New Mexico.

[b]The sum of each year from 1975 to 2000 inclusive on a straight-line basis. Note: It was estimated that about 13,500 tons of U_3O_8 was produced in the U.S. in 1973.

TABLE B-57 MINES & THEIR ORE PRODUCTION IN EACH OF THE CASES[a]

Year	Mines			Production per year (x 10^4) tons		
	FTFB	AFTF	NEE	FTFB	AFTF	NEE
1975	11	10	8	7.71	6.84	5.47
1980	29	13	31	20.88	9.07	21.96
1985	44	27	61	31.90	19.22	43.92
1990	53	41	126	38.45	29.38	90.65
1995	62	55	225	44.78	39.60	162.07
2000	70	70	359	50.54	50.54	258.26

[a]Based on the mines required for the year given.

recovered. These data are used to calculate rubber and steel requirements, shown in Table B-58. The unit requirements of steel and rubber for the mining equipment were obtained in telephone conversations with personnel at the Anaconda Mining Company. Estimates of manpower in engineering and supervisory positions, direct labor and total operations are shown in Tables B-59, B-60 and B-61. The amounts of steel and concrete needs of mining and milling plants are specified in Table B-62. The capital outlay for these materials is shown in Table B-63. Cumulative capital outlay for complete mining and milling facilities is presented in Table B-64. The power consumption for mining, transport to the mill and milling of uranium ore is specified in Table B-65. Finally, the water used in milling is presented in Table B-66. In summary, Tables B-57 through B-66 constitute a detailed account of the various materials and manpower requirements of the uranium mining and milling industry.

B-3-5 IMPACTS OF URANIUM MINING AND MILLING

Viewed in the context of extraction requirements, uranium is a good resource compared to other fuels. The summaries of requirements for the FTFB, AFTF, and NEE cases, shown in Tables B-67, B-68 and B-69, reveal no major impacts on materials and manpower. In addition, the expected demand for U_3O_8 in the future should offer sufficient incentive to attract the required capital. Assuming that sufficient numbers of mines are producing, uranium mining and milling represents a modest effort even for the NEE scenario. Currently, U_3O_8 is available at $8/lb. The amount of uranium needed to fuel the reactors in the FTFB case would increase the cost to approximately $21/lb. in the year 2000. The costs for the AFTF and NEE cases in the year 2000 are estimated at $14/lb. and $43/lb., respectively. At worst, for the NEE case, the corresponding increase in the cost of electricity would be 24 percent [Benedict-71].

Uranium mines are typically located in remote regions. This causes several problems. The fuel and materials needed to operate the mining equipment must be transported to the mine site. High capacity trucks or railroads are needed to transport the ore from the mine to the milling location. In addition, attracting labor to work in remote areas demands incentives such as good working conditions, comfortable living quarters and attractive salaries. However, the increased costs incurred to overcome these problems can easily be included in the price of the uranium.

The environmental impact of uranium extraction is associated with the disposal of waste products from the mining and milling operations. Water leaving the mines and mills requires treatment for removal of radioactive materials and acid liquids or suspensions. The effluents from uranium mills left after concentration of the ore amount to nearly 900 gallons per ton of ore. They are collected in settling ponds which must be fenced off and posted. The danger exists that effluent from tailings ponds may enter streams and ground water. Monitoring and control is a continuing responsibility of the industry.

TABLE B-58 RUBBER & STEEL REQUIREMENTS FOR MINING EQUIPMENT & TRUCKS FOR AN OPEN PIT MINE[a]
(In short tons x 10^3)

Year	FTFB		AFTF		NEE	
	Rubber, Tons	Steel, Tons	Rubber, Tons	Steel, Tons	Rubber, Tons	Steel, Tons
1975	1.6	16.9	1.4	15.0	1.1	12.0
1980	4.3	45.9	1.9	19.9	4.6	48.3
1985	6.6	70.1	4.0	42.3	9.1	96.6
1990	8.0	84.5	6.1	64.6	18.8	199.3
1995	9.3	111.2	8.2	87.0	33.6	356.3
2000	10.5	111.1	10.5	111.1	53.6	567.8

[a] An open-pit mine operated by the Anaconda Company in Grants, New Mexico.

TABLE B-59 ENGINEERING & SUPERVISORY MANPOWER FOR EACH OF THE THREE CASES[a]

(Person Per Operating Day)

Year	FTFB		AETF		NEE	
	Mines	Mills	Mines	Mills	Mines	Mills
1975	193	161	171	143	137	114
1980	522	435	227	189	549	458
1985	797	665	481	401	1098	915
1990	961	801	721	612	2266	1889
1995	1120	933	990	825	4052	3377
2000	1264	1053	1264	1053	6457	5381

TABLE B-60 OTHER MANPOWER FOR EACH OF THE THREE CASES[a]

(Other Persons in Labor Force Per Operating Day)[b]

Year	FTFB		AFTF		NEE	
	Mines	Mills	Mines	Mills	Mines	Mills
1975	3,659	3,049	3,249	2,707	2,599	2,166
1980	9,918	8,265	4,309	3,591	10,431	8,692
1985	15,151	12,625	9,131	7,609	20,862	17,385
1990	18,263	15,219	13,708	11,628	43,058	35,881
1995	21,272	17,727	18,810	15,675	76,984	64,153
2000	24,008	20,007	24,008	20,007	122,675	102,229

[a]Based on production for the Anaconda strip mine in Grants, New Mexico.

[b]Those other than engineers and supervisory personnel.

TABLE B-61 MANPOWER FOR EACH OF THE THREE CASES[a]

(Total Persons in Labor Force Per Operating Day)[b]

Year	FTFB		AFTF		NEE	
	Mines	Mills	Mines	Mills	Mines	Mills
1975	3,852	3,210	3,420	2,850	2,736	2,280
1980	10,440	8,700	4,536	3,780	10,980	9,150
1985	15,948	13,290	9,612	8,910	21,960	18,300
1990	19,224	16,020	14,429	12,240	45,324	37,770
1995	22,392	18,660	19,800	16,500	81,036	67,530
2000	25,272	21,060	25,272	21,060	129,132	107,610

[a]Based on production for the Anaconda strip min in Grants, New Mexico.

[b]In 1973 it has been estimated that there were 252 engineers and 4,786 other employees in mining and milling operations for U_3O_8.

TABLE B-62 CONCRETE & STEEL FOR MINING & MILL PLANTS

Years	FTFB		AFTF		NEE	
	Steel, tons	Concrete, yd^3	Steel, tons	Concrete, yd^3	Steel, tons	Concrete, yd^3
1976-80	1,098	7,320	186	1,240	1,374	9,160
1981-85	918	6,120	846	5,640	1,830	12,200
1986-90	546	3,640	846	5,640	3,894	25,960
1991-95	528	3,520	852	5,680	5,952	39,680
1996-2000	480	3,200	912	6,080	8,016	53,440

TABLE B-63 CAPITAL OUTLAY FOR STEEL & CONCRETE FOR AN OPEN-PIT MINE & MILLING PLANT

(Thousands of Dollars)[a]

Years	FTFB		AFTF		NEE	
	Steel	Concrete	Steel	Concrete	Steel	Concrete
1976-80[b]	911.34	161.04	154.38	27.28	1,140.42	201.52
1981-85	761.94	134.64	702.18	124.08	1,518.90	268.40
1986-90	453.18	80.08	702.18	124.08	3,232.02	571.12
1991-95	438.24	77.44	707.16	124.96	4,940.16	872.96
1996-2000	398.40	70.40	756.96	133.76	6,653.28	1,175.68

[a] Based on the number of mines required to meet U_3O_8 requirements for the various plans.

[b] Inclusive

TABLE B-64 CUMULATIVE CAPITAL OUTLAY IN 5-YEAR PERIODS FOR COMPLETE MINING & MILLING FACILITIES[a,c]

(Millions of Dollars)

Period[b]	FTFB	AFTF	NEE
1976-80	439.2	74.4	549.6
1981-85	367.2	338.4	732.0
1986-90	218.4	338.4	1557.5
1991-95	211.2	340.8	2380.8
1996-2000	192.0	364.8	3206.4

[a]Based on an estimate of an original investment of $24,000,000 for the complete mine and mill facilities.

[b]The final year of a period is inclusive.

[c]The total invested capital in mines and mills has been estimated to be approximately $95,000,000.

TABLE B-65 POWER CONSUMED IN MINING, MILLING & TRANSPORT OF ORE FROM MINE TO MILL

Year	Mines, Number			KWH. used (x 10^7)		
	FTFB	AFTF	NEE	FTFB	AFTF	NEE
1975	11	10	8	11.5	10.2	8.2
1980	29	13	31	31.1	13.6	32.8
1985	44	27	61	47.6	28.7	65.6
1990	53	41	126	57.4	43.9	135.4
1995	62	55	225	66.9	59.1	242.0
2000	70	70	359	75.5	75.5	385.7

TABLE B-66 WATER USED IN MILLING
(Gallons/Day) x 10^7

Year	FTFB		AFTF		NEE	
	Mines	Water	Mines	Water	Mines	Water
1975	11	2.1	10	1.9	8	1.5
1980	29	5.8	13	2.5	31	6.1
1985	44	8.9	27	5.3	61	12.2
1990	53	10.9	41	8.2	126	25.2
1995	60	12.9	55	11.0	225	45.0
2000	70	14.0	70	14.0	359	71.7

TABLE B-67 URANIUM MINING AND MILLING REQUIREMENTS FOR FTFB

Year	Number of mines	Laborers	Power (KWh x 10^7)	Water (Gal/Day x 10^7)	Steel[a] (T x 10^3)	Rubber,[b] (T x 10^3)	Concrete[c], (YD^3)	Capital, (millions of dollars)
1975	11	7,100	11.5	2.1	18	1.6	4,300	260
1980	29	19,100	31.2	5.8	48	4.3	11,600	700
1985	44	29,200	47.6	8.9	73	6.6	17,700	1,060
1990	53	35,200	57.4	10.7	88	8.0	21,400	1,280
1995	62	41,100	66.9	12.9	115	9.3	24,900	1,490
2000	70	46,300	75.50	14.0	115	10.5	28,100	1,650

[a]Both steel in mining equipment and in surface building construction.

[b]Rubber tires on mining equipment.

[c]Concrete for building foundations on surface for mill operations and mining.

[d]Includes investment in mill, open-pit mine with equipment, and land.

TABLE B-68 URANIUM MINING AND MILLING REQUIREMENTS FOR AFTF

Year	[a]Number of mines	[b]Laborers	[c]Power, (KWh x 10^{7})	[d]Water, (Gal/Day x 10^{7})	Steel, (T x 10^{3})	Rubber, tons (T x 10^{3})	Concrete, (YD^{3})	Capital, (millions of dollars)
1975	10	6,300	10.2	1.9	16	1.4	3,800	230
1980	13	8,300	13.6	2.5	21	1.9	5,000	300
1985	27	17,600	28.7	5.3	44	4.0	10,700	640
1990	41	26,700	43.9	8.2	67	6.1	16,300	980
1995	55	36,300	59.1	11.0	90	8.2	22,000	1,320
2000	70	46,300	75.5	14.0	115	10.5	28,000	1,650

[a]Number of open pit mines and mills equivalent to the Anaconda Co. operations in Grants, New Mexico.

[b]Total number of persons working in both mining and milling, about 10 percent of them in engineering and/or supervision.

[c]Total power used per year for mining, milling, and transport of ore from mine to mill.

[d]The water used in the milling operations only.

TABLE B-69 URANIUM MINING AND MILLING REQUIREMENTS FOR NEE

Year	[a]Number of mines	Laborers	Power, (KWh x 10^{7})	Water, (Gal/Day x 10^{7})	Steel, (Tons x 10^{3})	Rubber, (Tons x 10^{3})	Concrete, (YD^{3})	Capital, (millions of dollars)
1975	8	5,000	8.2	1.5	13	1.1	3,000	180
1980	31	20,100	32.8	6.1	50	4.6	12,200	730
1985	61	40,300	65.6	12.2	100	9.1	24,400	1,460
1990	126	83,100	135,4	25.2	207	18.8	50,400	3.020
1995	225	148,600	242.0	45.0	370	33.6	90,000	5,400
2000	359	236,700	385.7	71.7	589	53.6	143,500	8,610

[a]See footnotes for Tables B-67 and B-68

There is little radiation hazard to personnel in properly operated mines. The radioactivity of natural uranium ore is not significant. Concentration of radon gas and its products in the air of underground mines is prevented by high movement of air through the mines. The more significant health and safety hazard associated with uranium mining may be use of explosives to break up uranium bearing rock. Continued enforcement of regulations for the safe use of explosives will minimize this hazard.

B-4 OTHER SOURCES

Oil and gas, coal, and uranium are by far the largest of the sources of energy that will play an important role before the year 2000. There are many other sources, however, whose individual impacts are quantitatively small but which total to give the part called "Other" in the various scenarios. The most important of these are briefly discussed or referenced in this section.

Though these impacts are not large, some of these other sources are very important. Solar, because it is constantly renewable; fusion, because it's potential is so great; trash, because it is a step into a recycling economy.

B-4-1 HYDROPOWER

The energy in flowing water is convertible to electricity with minimal losses and presently provides about 16 percent of the United States electrical power capacity and 4 percent of the total energy production. Available sites are limited so the potential for expansion of this constantly renewable power source can be estimated rather well. By 1990 almost all the estimated "recoverable" conventional hydropower sites will be utilized. The power capacity then will be 82 GWe, slightly more than 45 percent of the 178 GWe available from all the sites in the United States [DOC-73]. Forty-five percent is the ratio of recoverable to available hydropower [ISGS-73]. Thus, in 1990 the installed hydropower facilities in the United States will be essentially complete. Long term changes will involve closing old sites because of silting up of reservoirs and mechanical failure of generators, but these are not problems on a twenty-five year time scale. The 82 GWe corresponds to 360 x 10^9 kWH of electrical energy (= 3.8 quads thermal) at the present capacity factor of 51 percent. Presumably this will persist, for hydropower is so well adapted to use during peak load hours.

Further expansion of hydropower involves <u>pumped storage</u>. This is not an additional source of energy but is simply an energy storage mechanism. During off peak hours part of the output of a standard (fossil fuel or nuclear) plant is used to pump water into a high reservoir. This permits the standard plant to operate at optimal efficiency for more nearly full time. Then, during peak demand time, the stored energy is recovered. Pumping time and efficiency vary, reasonable figures being about 3 kWH expended to pump up a 2 kWH capacity, and a pumping time 50 percent longer than generating time [FPC-70]. (Thus, if 200 MW are used continuously during off peak time to pump, then during peak time an extra 200 MW of capacity are available.) Pumped storage does not increase the amount of energy available, but where it can be installed it can effectively double the power rating of a plant.

Projections of both conventional and pumped storage capacity are summarized in Table B-70.

TABLE B-70 CONVENTIONAL AND PUMPED STORAGE HYDROPOWER[a]

Conventional (GWe)				Pumped Storage (GWe)			
Existing	Under Construction	Planned*	Total	Existing	Under Construction	Planned*	Total
51.6	8.3	21.9	81.8	3.7	7.3	58.8	69.8

Timetable for Conventional[b]

	1980	1985	1990	1995	2000
Quads	3.1	3.4	3.8	3.8	3.8

*Planned to come on line before 1990

[a]FPC-70

[b]Capacity factor of 51%, linear interpolation of FPC generating capacity figures out to 1990.

B-4-2 OIL FROM SHALE

Oil shale is a sedimentary rock containing an organic matter called kerogen. This shale is found in many areas of the United States, however, the richest and largest area is the Green River Oil Shale Formation in Colorado, Utah, and Wyoming (Figure B-5). Shale in this area is estimated to yield from 25 to 35 gallons of oil per ton of shale depending upon the specific location. This oil shale region covers an area of approximately 17,000 square miles and contains more than 600 billion barrels of oil [Colony-74]. Estimates indicate that 80 billion barrels of this reserve are recoverable using present technology.

The shale oil, or synthetic crude, can be recovered using present technology, specifically room and pillar mining techniques coupled with a retorting or pyrolysis process. This synthetic crude may then be reduced to a low sulfur heating oil and naphtha. One ton (2000 lbs) of 33-gallon-per-ton oil shale will yield 1648 pounds of processed or spent shale, 252 pounds of heating oil, 71 pounds of high heating value gas, and 23 pounds of water [Atwood-74].

There are a number of companies currently contemplating or pursuing the development of oil shale properties. The rate of growth of the oil shale industry as a source of synthetic crude to supplement the U.S. energy supply depends, among other things, on economic and environmental constraints. Estimates of the potential production of oil from shale vary. Projections used in this study are shown in Figure B-6 for comparision with previous estimates of the National Petroleum Council and Shell Oil Company [Stewart-74]. These projections have also been evaluated in terms of capital, steel, concrete, and manpower requirements, as shown in Table B-71.

There are a number of impacts which are of particular concern in the area of shale oil mining and production. Among the major impacts are the tremendous quantities of water required, and the minimal ground and surface water supplies in the Green River Basin. The processing of oil shale results in approximately a 20 percent increase in the volume of the spent shale, precipitating a major problem in spent shale disposal. In addition, the oil shale industry will also have effects on the surface topography, water quality, the flora and fauna of the area, and possible smog near refining facilities. Further,there will be substantial efforts required in the restoration and revegetation of the mining and spent shale areas.

The advent of the oil shale industry will certainly have an economic impact on the communities in the vicinity of the Green River formation. Studies have indicated that a program to increase the rain and snowfall in the Rocky Mountains would increase the surface water substantially, thereby providing additional water for the development of energy resources, such as oil shale, and more water for other states drawing water from the Colorado River [Coates-74-1]. This weather modification, however, may have effects on the surrounding areas.

B-4-3 SOLAR ENERGY RESOURCES

The sun radiates energy outward in all directions. Outside the earth's atmosphere, this energy flux is approximately 1350 watts/sq in (430 BTU/hr sq ft)

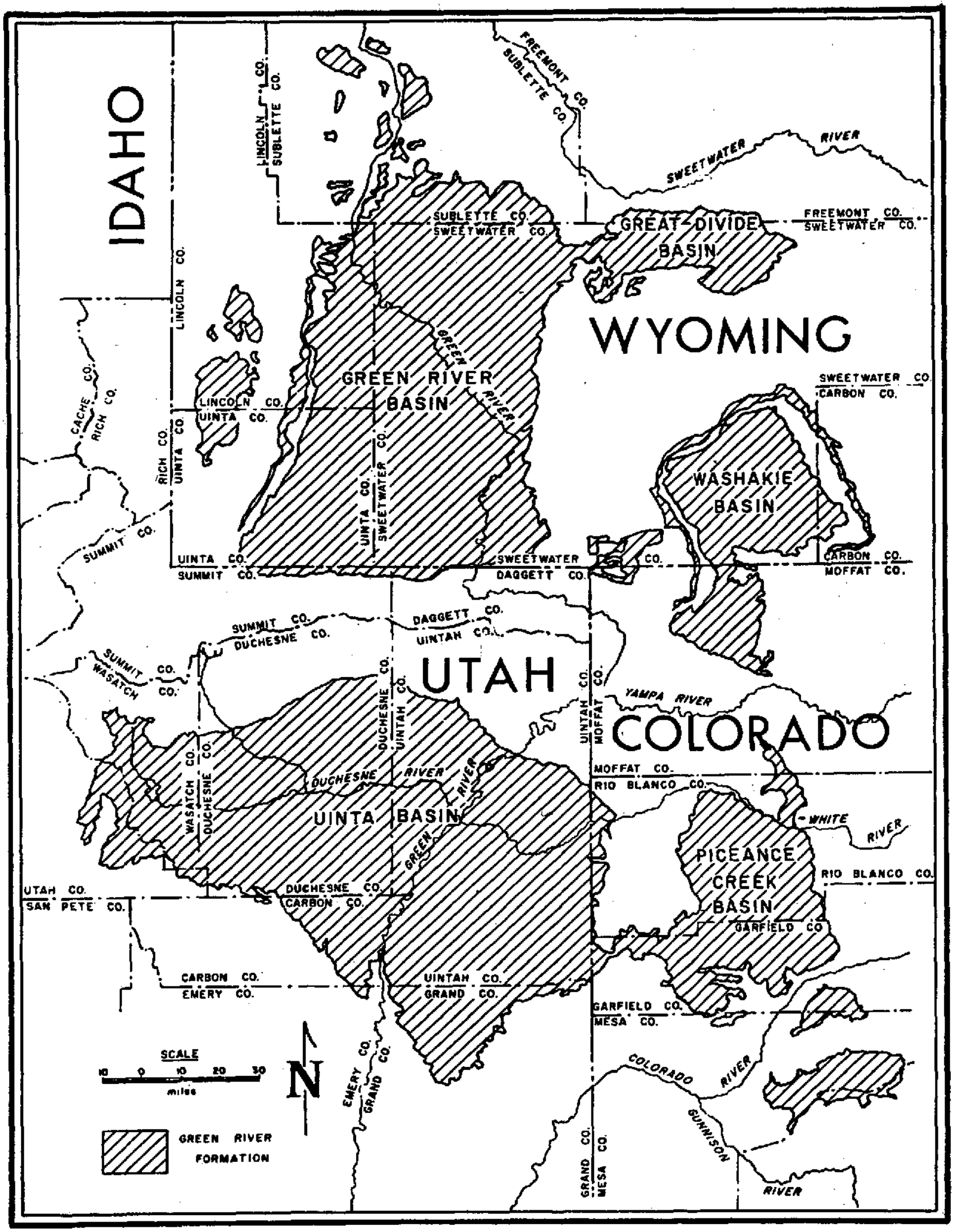

FIGURE B-5 EXTENT OF THE GREEN RIVER OIL SHALE FORMATION IN COLORADO, UTAH, AND WYOMING [Colony-74]

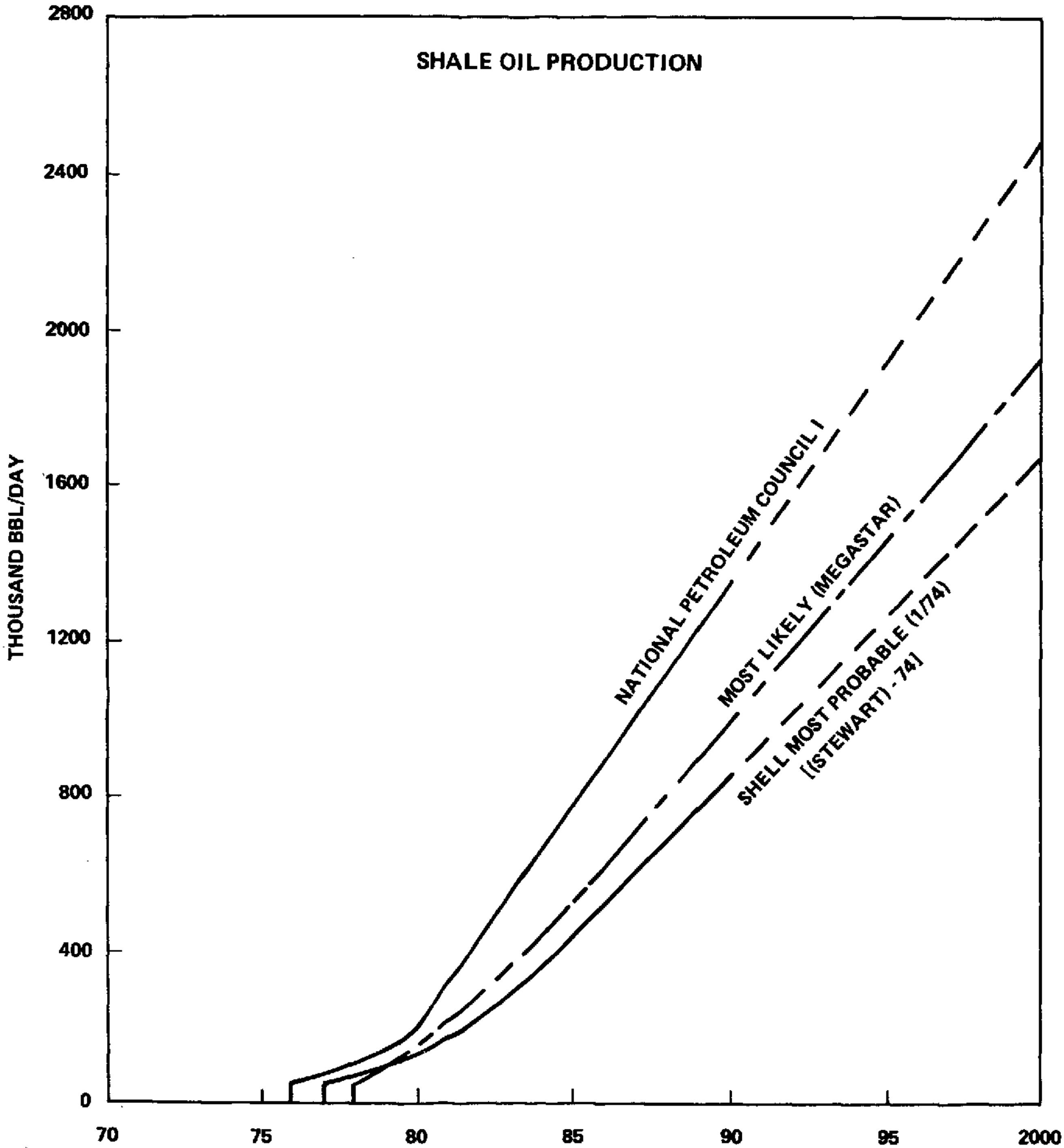

FIGURE B-6 PROJECTIONS OF SHALE OIL PRODUCTION

TABLE B-71 MANPOWER, CAPITAL, STEEL AND CONCRETE REQUIREMENTS FOR PRODUCTION OF OIL FROM SHALE[a]

Year	Production Level[a]		Manpower[b]			Added Production[a]				
	Thousands BBL/D	(10^{15} BTU)	Engineers	Production	Miners	5-Year Period	Thousands BBL/D	Capital[c] Millions	New Steel[d] (Structural) Thousands, Tons	Concrete Thousands, yd^3
1975	0	0	-	-	-	1971-75	0	-	-	-
1980	50	0.1	120	320	450	1976-80	50	$ 425	20	55
1985	500	1.0	620	2,700	4,000	1981-85	450	3,825	180	495
1990	950	1.9	1,100	5,000	7,500	1986-90	450	3,825	180	495
1995	1,400	2.9	1,600	7,200	1,100	1991-95	450	3,825	180	495
2000	1,850	3.8	2,000	9,300	13,500	1996-2000	450	3,825	180	495

[a]Based on estimates projected from one oil shale facility [Vawter-74, Schulman-74].

[b]Manpower employed in the oil shale industry in the year specified.

[c]1972 dollars

[d]Does not include retorting vessels and piping.

when the sun is directly overhead. At a point on the earth's surface, the sun's energy flux may reach a value of 1100 watts/sq in (350 BTU/hr sq ft) depending, among other things, on the location of the sun, the composition of the atmosphere, and the weather [Terrastar-73]. Solar energy is lost by absorbtion and scattering due to the dust and water vapor in the air. In spite of the atmospheric loss, solar energy is clean; it can be obtained without polluting either the atmosphere or water, and without sacrificing irreplaceable resources.

The average annual irradiance is the greatest near the equator and diminishes across the United States proportional to the distance from the equator. Other factors, such as elevation and predominant weather conditions result in an average annual irradiance distribution as shown in Figure B- 7 . The mean daily solar irradiance (BTU/sq ft day) on Arizona ranges from 1000 in December to 2,600 in June, resulting in an average of 1900 [Terrastar-73]. In New England, the mean daily solar irradiance ranges from 400 in December to 1600 in June, resulting in an average of 1100 for the year. These solar radiation or energy flux values are sufficient in most cases to provide several times the amount of energy needed for the heating/cooling of typical houses if all were captured.

Solar energy is generally rated in terms of a direct component and a diffuse component. On a clear day diffuse radiation will account for less than 10 percent of the total, whereas on cloudy days, nearly all of the radiation will be diffuse [Terrastar-73]. Specific data on the proportion of direct and diffuse irradiance is necessary for detailed analysis of the solar energy potential for the U.S. There are as yet, however, only limited insolation measuring systems. A small network of solar insolation data collection sites currently provides data to the National Climatic Center at Asheville, North Carolina. These data are collected and processed and do provide an indication, however limited, of the total available solar energy in the United States.

Utilization of solar energy for home heating and cooling is discussed in Appendix C-3, and its use for electric power generation in Appendix C-1-3.

B-4-4 GEOTHERMAL ENERGY RESOURCES

Geothermal energy (the natural heat of the earth) is relatively clean energy which, if developed to its full potential, could have a significant impact on the energy requirements of the United States. There have been numerous optimistic estimates of the generating capacity possible from geothermal sources, However,recent projections appear to be more realistic for purposes of the present study. These projections are shown in Figure B-8 . In addition to providing an energy source for electricity generation, geothermal energy could be used directly in industrial processes, space heating, agriculture, refrigeration, desalination, and the production of mineral by-products, thereby reducing the demand for other forms of energy.

Geothermal energy results from the difference in temperature between the surface of the earth and its center. Temperature measurements in wells and mines show temperatures ranging from 40°C to 380°C (104°F to 716°F) at shallow depths (less than 4 km). Temperatures continue to rise to 200°C to 1000°C (392°F to

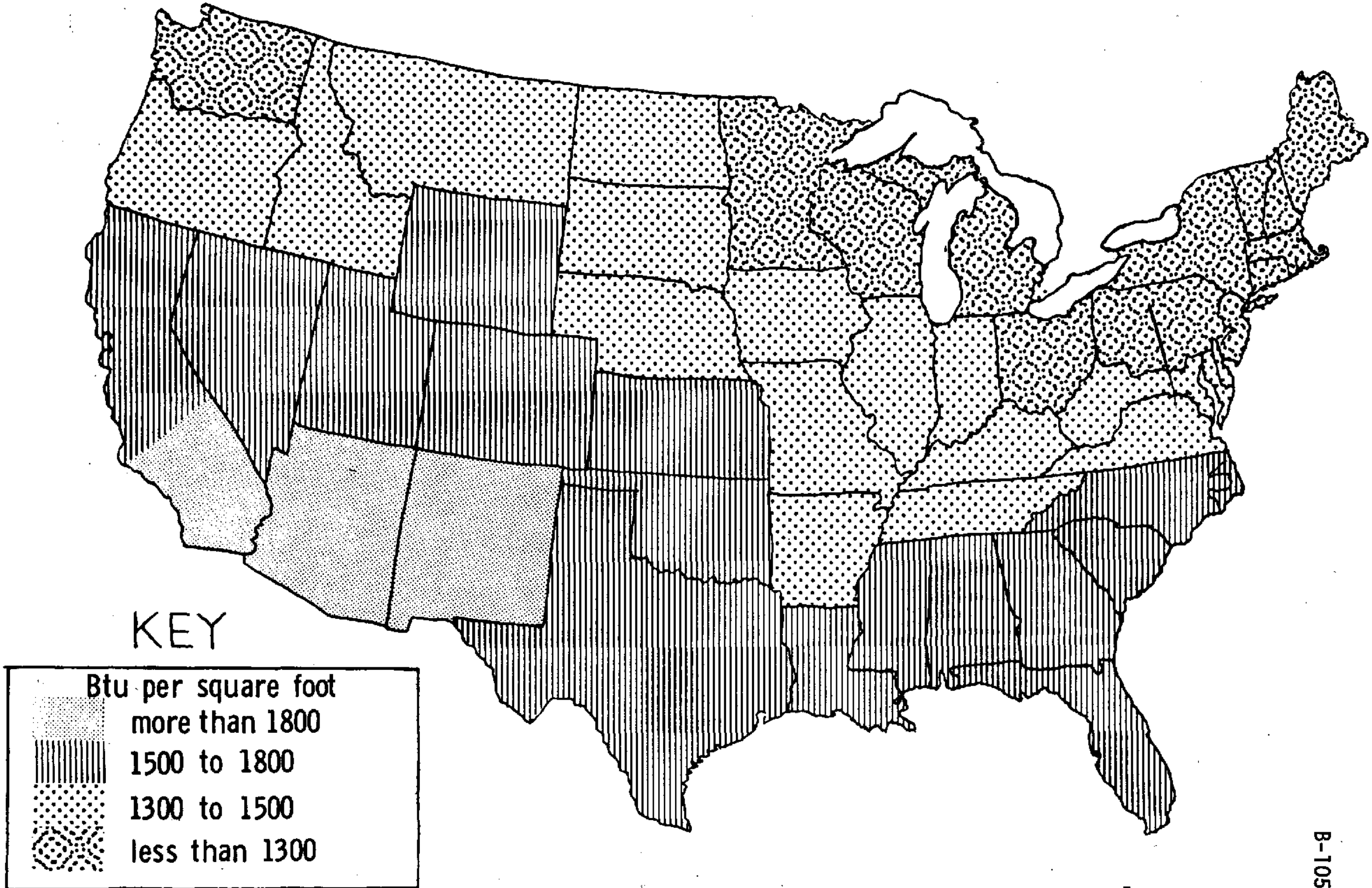

FIGURE B-7 ANNUAL MEAN DAILY SOLAR IRRADIANCE [Terrastar-73]

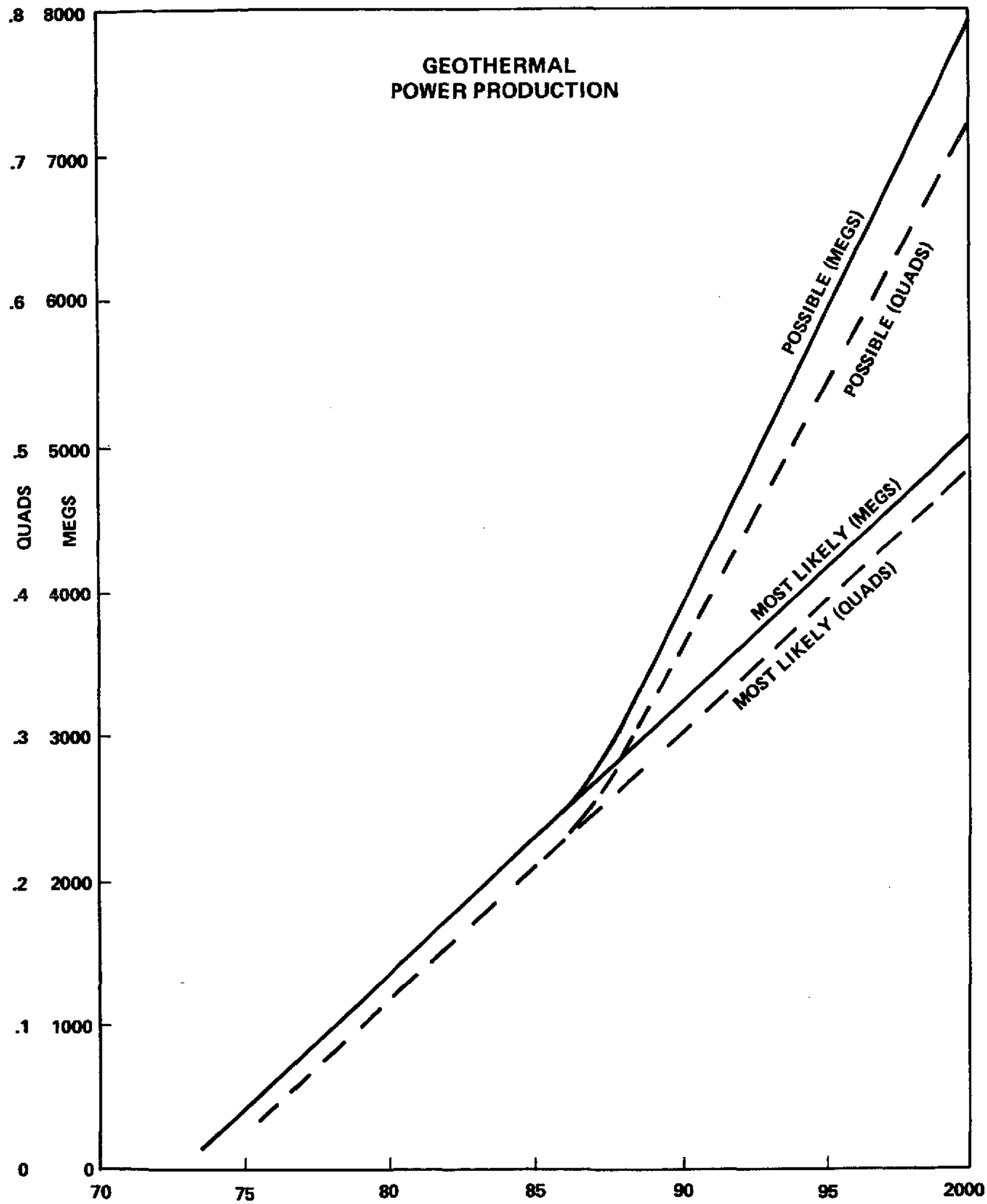

FIGURE B-8 PROJECTIONS OF GEOTHERMAL POWER PRODUCTION

1832°F) at the base of the continental crust (25-50 km deep) to perhaps 3500°C to 4500°C (6332°F to 8132°F) at the earth's center [Peck-72]. The thermal energy is stored within the earth in steam, water, and solid or permeable hot rock. With present technology, only vapor dominant sources are used for electrical generation systems.

The world-wide average heat flow from the earth center is 1.5 x 10^{-6} calories/sec-sq cm, and geothermal reservoirs are found in regions where the heat flow ranges from 1.5 to 5 times the world-wide average. These reservoirs generally occur in areas of young volcanism, igneous intrusion, mountain building, and along the margins of the earth's crustal plates. The average rate of heat flow from the earth's surface is estimated to be 957,000 trillion BTU/year. Producing at the rate of 4 x 10^5 MW (1970 mean world usage rate) and assuming a 13 percent conversion rate from geothermal energy to power, the earth would cool down only 1 degree in 41 million years [Anderson-73].

In the United States, the magnitude of geothermal reservoirs is poorly defined. Estimates, however, may be inferred from the distribution of hot springs [Waring-65]. These hot springs are found primarily in the western states of California, Nevada, Oregon, Idaho, Utah, New Mexico, Wyoming, Arizona, Colorado, Hawaii, and Alaska, as shown in Figure B-9 . The geysers in northern California are a producing geothermal-electrical generation source (approximately 400 MW).

In order to assess the magnitude and location of the United States' geothermal resources, an expanded development program is needed. Such a program should include the development of better estimation and exploration methods, improvement of production and utilization technology, and analysis of environmental effects and legal aspects. Consideration of all of these factors is essential to the full development of the United States' geothermal energy resources.

B-4-5 WIND POWER

The use of wind energy is not a new idea. The oldest and most wide-spread application was to drive sailing ships. With the arrival of cheap fossil fuels in the 19th century, the sailing ships were quickly replaced by coal and oil burning ships. On land, the windmill is also an ancient source of energy generation. It seems to be Persian in origin with a vertical axis in place of the familiar horizontal format. The vertical windmill spread through the Islamic world after the Arab conquest of Iran, and later to China with the Mongols. When it appeared in Eupope during the 11th century, the axis was inclined 30° to the horizontal. Windmills helped the Netherlands to become the world's most industrialized nation by the 17th century. In the western United States, windmills were used for pumping water and running sawmills.

There are extensive regions of moderate to strong winds in the United States, particularly off the eastern coast, through the Great Plains and in the great length of the Aleutian chain of islands. These winds vary in suitability for driving modern high-speed wind turbines, and thereby electrical generators. Economics of a proposed wind power facility at a specific location can be quickly

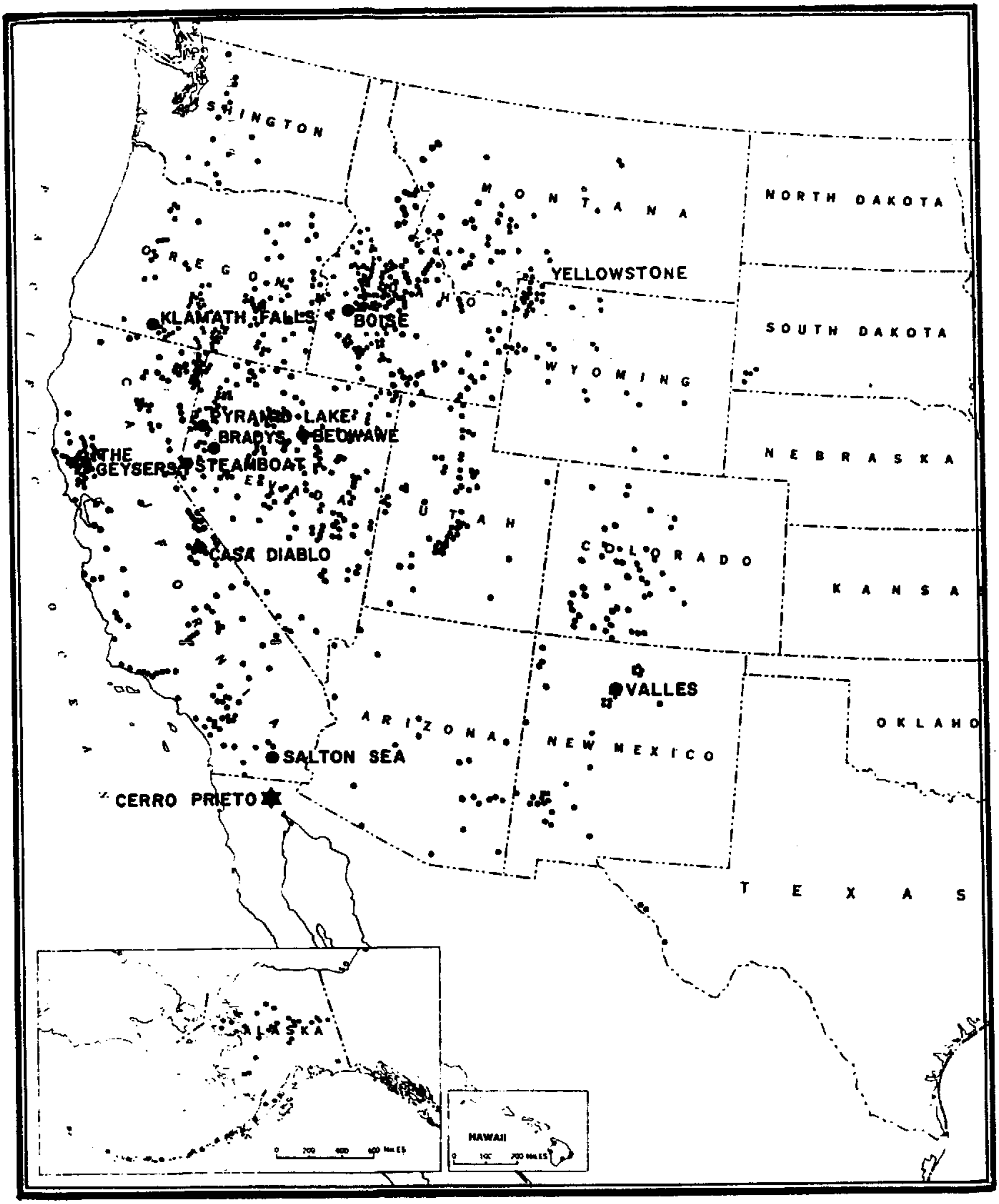

FIGURE B-9 HOT SPRINGS (Small dots), KNOWN GEOTHERMAL AREAS (Large dots), AND PRODUCING GEOTHERMAL FIELDS (star), IN THE WESTERN UNITED STATES [Waring-65]

ascertained when a few parameters of the local wind have been evaluated. The technical and scientific basis for windpower have been known for centuries. Only low-cost fuel and cheap heat engines were able to remove it from popular practice. However, fuel and heat engines are no longer low-cost, expecially low sulfur fuel and nuclear engines.

The theoretical limit for an ideal windmill is 59 percent. Good aerodynamic design can generate 75 percent of the theoretical maximum, or 44 percent. The efficiency η is related to the output power W by

$$W = \eta E,$$

where E is the power in the wind passing the windmill. The power output for any wind velocity and propeller or blade diameter is

$$W = \frac{\eta P^2 U^3}{250} \text{ watts}$$

where P is the diameter in feet, U is the wind speed in miles per hour.

The above equations can be programmed to find the number of windmills necessary to satisfy part or all of an energy budget. The number and density, of windmills for power will depend on:

the wind speed at the site;
the daily and monthly distributions of wind speed;
the size of the rotating blade or propeller;
the efficiency of the system;
the height of the propeller above the surface of the earth;
the surrounding terrain.

B-4-6 OCEAN THERMAL DIFFERENCES

W. E. Heronemous, University of Massachusetts, proposed use of the ocean thermal differences in the Gulf of Florida and in the Gulf of Mexico. Solar energy heats the surface of the sea, between the Tropics of Cancer and Capricorn, to a temperature that does not drop below 27°C. In the polar regions, in the Arctic and in the Antarctic areas, the intensive summer insolation melts the previous year's accumulation of sea ice and snow. The nearly freezing water moves toward the equator at a temperature at 2°-4°C in a level varying from 1000 to 2000 feet. The temperature difference between the warm surface water and the cold subsurface water is usually 28°C.

The Unites States has no adjacent tropical seas, but the Gulf Stream pumps 30 million cubic meters per second of warm near-tropical surface water into the Gulf of Florida. The temperature differences between the warm surface waters and the subsurface cold waters are always more than 15°C and reach 23° to 25°C for six months of the year. The Carnot efficiency is given by:

$$\text{Efficiency} = \frac{T_2 - T_1}{T_2} \times 100 \text{ percent}$$

where T_2 is the warm water temperature and T_1 is the cold water temperature, both

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in degrees Kelvin. The efficiencies are low, but the quantities involved are extremely large.

C. Zener and others at Carnegie-Mellon University indicated that, with a 22°C temperature difference, the actual efficiency is only half of the ideal Carnot efficiency. Many of the system losses are associated with pumping fluid from the warm surface to the cold surface.

The cost per kilowatt was estimated by J. H. Anderson to be $166 in 1966. It was found from:

Total cost + 1.6 [(cost of boiler and condenser) + (cost of other components)]

where 60 percent covers assembly costs, engineering, and overhead. Half of the total component cost is for the boiler and condenser.

The first investigation in sea thermal energy was made by the French scientist Jacques Arsene d'Arsonval in 1882. This was followed by an American engineer and two Italian scientists. The first operational sea thermal energy plant was built by Georges Claude, another French scientist, in 1929, at the age of sixty years. He was only able to produce 22 kilowatts of power, operating on a temperature difference of 14°C.

The system proposed by J. H. Anderson will generate 100 Megawatts. With the cost per kilowatt mentioned earlier, the total construction and assembly costs for the sea plant would be $16,647,000. Yearly costs would be $1,870,000, and the cost per kilowatt hour would be 0.3 cent. A 620 Megawatt nuclear power plant at Oyster Creek was estimated to cost 0.36 cents per kilowatt-hour. These are initial costs. Fuel for the nuclear plans is a recurring cost each year.

Another parameter is the location of a sea thermal energy plant. The useful areas for the United States are near the state of Florida and off the Southern coast of California.

B-4-7 FUSION

Extracting energy from controlled fusion is an exciting notion. At present, it is purely speculative: the relevant figure of merit is called the Lawson criterion and existing experiments fall several orders of magnitude below this number. There are two principal approaches: magnetic confinement of low density plasma for a long time, and inertial confinement of very high density material for a very short time. Magnetic confinement has been investigated for more than twenty years; its history has been one of discovering and ameliorating a series of plasma instabilities that prevent long-term confinement. Inertial confinement is rather new to the experimental scene, although the calculations go back to about 1960.

Either method as presently conceived utilizes the D-T reaction which yields a 14 MeV neutron whose interaction with a lithium blanket gives up energy as heat and breeds new tritium. The limiting factor is then the supply of lithium

but the energy out per pound of lithium depends on unknown details, so a BTU content cannot be placed on the lithium reserves.

A second generation fusion reaction utilizes the D-D reaction. This releases a large fraction of the energy as charged particle kinetic energy. The limitation seems to be the availability of deuterium, a huge amount, but again, the actual energy obtainable per pound of deuterium dependson presently unknown factors so an energy content cannot be placed on reserves.

All that is certain about controlled fusion is the lower limit on available energy: zero.

B-4-8 TRASH

Burning garbage for its energy content rather than simply disposing of it is likely to remain a small part of the United States energy system, but will probably become a good example of the conservation ethic. "Trashpower" is essentially an energy conversion scheme and is discussed more fully in Appendix C-2-3.

B-5 LIMITS TO EXPONENTIAL GROWTH

Table B-72 has been included to indicate how long the United States could depend on various depletable energy resources if their use increases at given rates. Depletion times assuming various use growth rates have been calculated, even though in some cases (coal and oil shale) use has not been increasing in recent years.

TABLE B-72. TIME UNTIL ENERGY RESOURCES ARE DEPLETED

Energy Source	Present Annual Consumption[1] (Quads)	Resource Base Estimates (Quads)		Years at Percent Annual Rate of Growth			
				0%	2%	4%	6%
Coal [2]	12	Low	33,600	2800	202	118	85
		High	88,600	7383	250	142	102
Petroleum	23	Low [3]	714	31	24	21	17
		High[2]	3,830	166	73	51	40
Nat. Gas	21	Low[3]	668	32	25	20	18
		High[2]	2,370	113	59	42	34
Nuclear[4]	2	Low	1,176	590	127	80	60
		High[5]	-	-	-	-	-
Shale Oil[2,6]	-	Low	11,900	548	124	78	59
		High	34,160	1485	171	102	75

[1]Consumption from domestic sources.

[2][TERRESTAR-73].

[3]Recent industry estimates of known and expected resources [Gillette-74].

[4]Present use and resource base are in terms of thermal BTU. Resource base assumes production only for \$30/lb. U_3O_8 [Hottel-71], and that only U_{235} is used for fission. Generation efficiency of 30% has been used.

[5]The upper limit for U_3O_8 availability is determined primarily by economic costs; further, breeder technology can increase the energy availability by a factor of 130. Hence "the energy potentially available from the fissioning of uranium and thorium is at least a few orders of magnitude greater than that from all the fossil fuels combined." [Sci. Am.-71]

[6]Times calculated for shale oil are for total years until <u>all</u> domestic oil resources (conventional plus shale) have been depleted.

APPENDIX C. GENERATION AND CONVERSION

This appendix is devoted to a discussion of generation and conversion. Electricity generation from uranium, fossil fuels and solar energy are discussed respectively. Then, a brief description of various methods of generating synthetic fuels is presented. Finally, the possibility of heating and cooling homes using solar energy is discussed. The present situation, unit requirements, path requirements, and impacts of each of these methods of generation or conversion is discussed.

C-1 ELECTRICITY GENERATION

This section is divided into three parts: generation of electricity from uranium, fossil fuels, or solar energy.

C-1-1 NUCLEAR

One of the reasons nuclear energy is viewed by many people as at least a partial solution to the current energy problem is that a great deal of energy is available in a small quantity of matter. One gram of uranium or thorium, if completely fissioned, will release about 1.0 MWDt of energy, which is equivalent to about 2.5 Tonnes of coal. However, nearly-complete utilization is only possible with breeder reactors. In fact, only about 1 percent of the potential energy of the uranium is available in burner reactors.

Another incentive for using uranium to generate electricity is the savings in fossil fuels which are needed for other energy uses. According to the Atomic Industrial Forum Report [AIF - 73] assuming annual plant use factors of 80 percent (probably high -- it appears that the report actually used 50 percent) and equivalent full-power lifetimes of 85 GWe of nuclear power would save about 2 and one-half million barrels of oil per day (.01 quads) or 21 billion barrels of oil (122 quads) over the life of a 1.0 GWe plant.

Before the requirements of discussing nuclear power plants, a brief introduction to the nuclear fuel cycle is presented.

Nuclear Fuel Cycle

Figure C-1 summarizes the various steps in the fuel cycle and indicates the annual quantities of fuel materials required for routine operations of a 1,000 MWe light water reactor. Each of these steps are discussed briefly below.

Exploratory effort will be needed in the future to supplement the world's uranium supply. Some of the requirements -- drilling rigs, geologists, and analytical instrumentation -- will simultaneously be needed for oil exploration. Thorium production may also need to be expanded.

The conversion of U_3O_8 ("yellow cake") to UF_6 purifies the concentrate by removing about 20 wt. percent non-uranium impurities, including several alpha-emitting daughters [Shelley - 74]. The process, utilizing HNO_3 and HF (requires special handling), yields 99.99 percent pure UF_6, which is shipped in solid form in 10-ton casks for further processing.

The enrichment process increases the ratio of U-235 to U-238. The term "Separative Work Unit" (SWU) defined as a measure of the effort expended in the plant to perform the enriching services, is indicative of the size of an enrichment plant. Although Figure C-2, which illustrates the SWU concept, was drawn for a gaseous diffusion process, other (perhaps better) ways to separate the uranium isotopes are currently under development. Enrichment is not necessary for some reactors; in particular, the Canadian heavy-water moderated plants (CANDU) use natural uranium. On the other hand, CANDU reactors require isotopic separation of another kind -- separation of deuterium from hydrogen. However, hydrogen separation is easier and less energy-intensive than uranium separation; an 800 Tonne/yr plant using a combination hydrogen sulfide exchange and electrolysis uses about 50 MWe and 200 MWt (steam) [Spray - 74].

Fuel fabrication plants manufacture pressed and sintered pellets of UO_2, PuO_2, and/or ThO_2, which are sealed in zircalloy or stainless steel tubes. Bundles of these tubes are assembled and end-fittings attached to make fuel elements, whose design have not been standardized. The High Temperature Gas-Cooled Reactor (HTGR) uses a special U/Th carbide fuel that requires a special fabrication facility and that will increase the demand for thorium.

Six types of reactor power plants currently appear to have sufficient backing to become sizable parts of a nuclear economy:

Pressurized-Water Reactors (PWRs): These reactors are marketed worldwide by several companies, including Westinghouse and Babcock & Wilcox. As of 1973, 22 PWRs were operating in the U.S. and 9 others in the world.

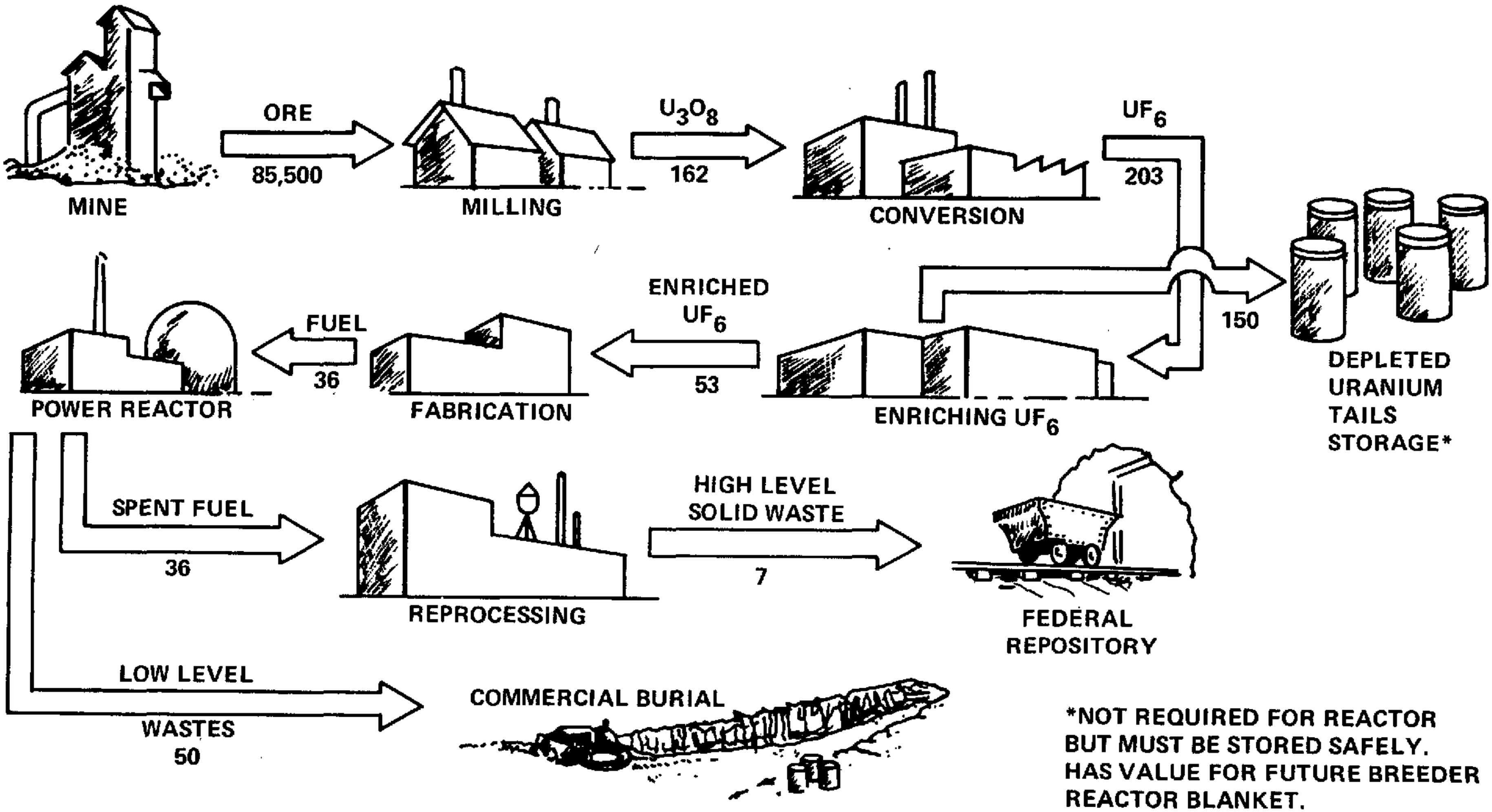


FIGURE C-1 ANNUAL QUANTITIES OF FUEL MATERIALS REQUIRED
FOR ROUTINE (EQUILIBRIUM) OPERATION OF 1,000 MWe LIGHT WATER REACTOR

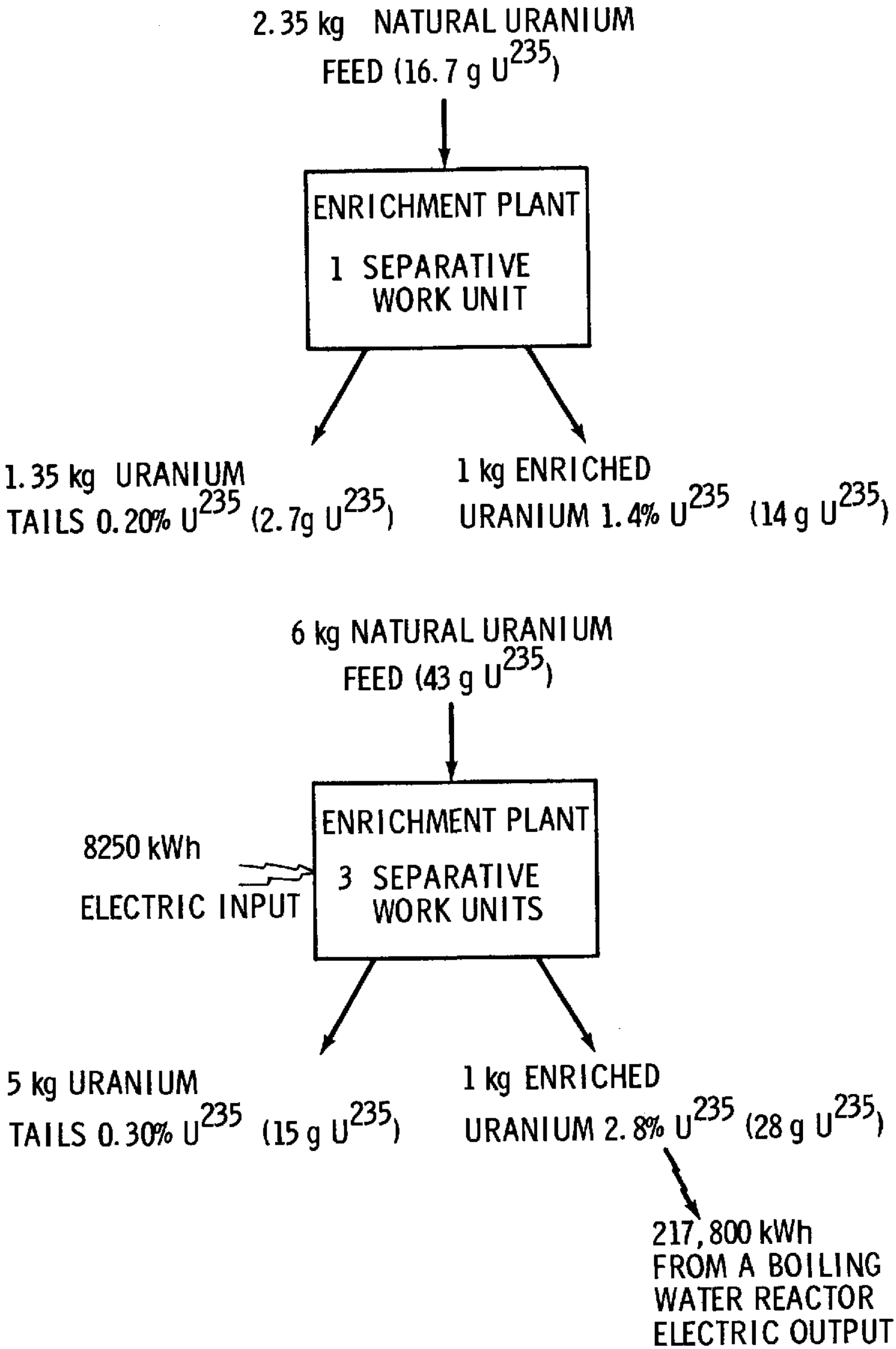


FIGURE C-2 ILLUSTRATIVE DEFINITION OF SEPARATIVE WORK UNIT [JCAE-73-1]

Boiling-Water Reactors (BWRs): This General Electric design is used in 18 plants now operating in the U.S. and 13 others elsewhere. Future commitments include 44 in the U.S. and 61 in the rest of the world.

High Temperature Gas-Cooled Reactors (HTGRs): This design, promoted by Gulf General Atomics, Inc. and by the British Nuclear Energy Board, is currently used in two plants in the U.S.; England and France are presently operating 31 CO_2-cooled (rather than helium) reactors; however, no additions of this type are planned. Fourteen HTGRs have been ordered for use within the U.S. and 12 outside. One advantage of HTGRs is their 40 percent thermal efficiency as opposed to 32 percent for water-cooled reactors.

Natural Uranium fueled. Heavy Water Moderated Reactors (CANDUs) (marketed by Canada): Although there are no CANDUs presently operating in the U.S., Consolidated Edison is buying power from Ontario Hydro which uses CANDUs [WER - 74]. Six plants are operating and 19 more are planned in Canada. Worldwide, 3 additional reactors are in service and 10 are planned [AEC - 74].

Liquid Metal Fast Breeder Reactors (LMFBRs): This advanced concept, promoted by U.S.A.E.C., France, USSR, West Germany, England, and Japan, is based on the principle that the reactor can produce more fuel than it uses. If projected breeding ratios of 1.2 - 1.5 were realized, mining requirements would be greatly reduced. Another important incentive for developing the breeder reactor is that it can utilize U-238 (99.7 percent of natural uranium), thereby extending uranium supplies from decades to millenia.

The Light Water Breeders (LWBs): The basic fuel in LWBs is Th-232 which can absorb a neutron to give U-233 (or absorb three neutrons to form U-235). Although any combination of fissile isotopes can be used in the core, calculations using U-233 indicate that a breeding ratio of 1.02 is possible [Bus. Wk. - 74]. Although present PWRs can utilize the LWB concept, the outside fuel elements must be replaced with beryllium reflector blocks with a resultant 10-40 percent loss in power output. The LWB concept will be tested in the Shippingport reactor by Adm. H.G. Rickover.

Fuel reprocessing includes recovering uranium and plutonium from the spent fuel elements and processing the radioactive waste materials. Fuel burning is limited by pressure buildup in the fuel tubes and reactivity loss due to fuel exhaustion and fission product poisoning. Since all of the available uranium is not used, reprocessing must include a separation technique for reclaiming the unused fuel as well as a means for extracting the

plutonium produced in the reactor. The spent fuel elements are chopped up and dissolved in nitric acid. Then a solvent extraction process, which is about 99.5 percent efficient, is used to remove the uranium and plutonium. The resulting effluent is high level radioactive waste, which will be stored under water until the AEC decides the final form required for shipment to a waste disposal area. The plans for ultimate waste disposal are highly speculative at this point. A more detailed discussion of the waste disposal problem is presented in the impacts section.

Present Situation

A brief discussion of the present situation in each of the steps of the nuclear fuel cycle is presented prior to discussing the requirements for each. The mining and milling discussion can be found in Appendix B. The industrial capabilities in the fuel manufacturing phase of the nuclear industry are summarized in Figure C-3.

Conversion of U_3O_8 to UF_6. Three plants capable of converting U_3O_8 to UF_6 are currently operating in the U.S.: Kerr-McGee's 5,000 ton/yr plant (expected to expand to 10,000 ton/yr) at Sequoyah, Oklahoma; Allied Chemical's 14,000 ton/yr plant near Metropolis, Illinois; and the A.E.C.'s 8000 ton/yr plant at Fernhold, Ohio (not shown in Figure C-3). These relatively small chemical plants have operating staffs of about 70 persons each and are estimated to cost about the same as the Kerr McGee plant -- $25 million [Shelley - 74].

Fuel Fabrication. The conversion of enriched uranium hexafluoride (UF_6) to uranium dioxide (UO_2) and the processing of the UO_2 into pellets are, to a large extent, performed in the same facilities and by the same companies that fabricate the finished fuel assemblies. In fact, each of the major nuclear steam system suppliers (G.E., Westinghouse, Babcock & Wilcox, and Combustion Engineering) has its own UO_2 fuel fabrication facilities. Exxon Nuclear, Gulf General Atomic (carbide fuels for HTGRs) and the Canadians (a small fuel fabrication facility can be purchased along with the CANDU reactor [CANDU - 73]) also have fuel fabrication facilities (See Figure C-3). Construction of typical facilities, such as the 250 Tonne/yr Exxon Nuclear Facility near Richland, Washington, and Westinghouse's 1200 Tonne/yr plant near Columbia, South Carolina, cost about $50,000/ Tonne/yr. These plants, using heavy equipment, such as presses, lathes, and swaging machines, are quite labor-intensive, requiring about 1 person per Tonne/yr [Namath - 74].

Both Exxon and Westinghouse plan to develop mixed oxide fuel fabrication facilities to recycle plutonium. Fabrication plants for plutonium fuel which must be handled in glove boxes and requires tighter security and more health physics surveillance, are estimated to cost about $200,000/Tonne/yr [Shelby - 74] and $65 (Canadian)/KG for CANDU fuel [Spray - 74].

X – DENOTES PRESENT DOMESTIC CAPABILITY F – DENOTES FUTURE DOMESTIC CAPABILITY

CAPABILITY	AGNS	ALLIED	A.I.	B&W	(B&W) NUMEC	(B&W) NUMEC	B.M.I.	CE.	ENC	GAC	GAC	GAC	G.E.	G.E.	G.E.	K.Mc	K.Mc	N.I.	NCM	N.F.S.	N.F.S.	NM	TNS	TEXAS	U.N.C.	U.S.N.	W	W	W	CAPABILITY	
$U_3O_8 \rightarrow UF_6$																	X													$U_3O_8 \rightarrow UF_6$	CONVERSION OF ORE CONCENTRATES TO UF_6
$UF_6 \rightarrow UO_2$				F	X			F	X						X	X				X									X	$UF_6 \rightarrow UO_2$	CONVERSION OF ENRICHED UF_6 TO UO_2
UO_2 PELLETS				F	X			X	X						X	X				X								X	X	UO_2 PELLETS	PRODUCTION OF UO_2 PALLETS FROM UO_2 POWDER
UO_2 FUEL FABR.				X	X			X	X						X	X												X	X	UO_2 FUEL FABR.*	FABRICATION OF FUEL ELEMENTS CONTAINING UO_2 PALLETS*
CARBIDE FUELS			X			X				X	F					X			X	X								X		CARBIDE FUELS	PROC. AND/OR FABR. OF HIGH TEMP. FUELS, i.e. CARBIDE-COATED PARTICLES, ETC.
SPECIAL FUELS			X			X				X	F					X						X		X		X				SPECIAL FUELS	PROC. AND/OR FABR. OF SPECIAL FUELS, i.e. RESEARCH REACTOR, U-Al, HFIR, EBR-II, CP-5, ETC.
U-233 FUELS						X						F								X										U-233 FUELS	PROC. AND/OR FABR. OF FUELS CONTAINING U-233
THORIUM						X				X	F					X			X	X			X							THORIUM	PROC. AND/OR FABR. OF CORE COMPONENTS CONTAINING THORIUM
Pu FUELS			X	X		X		F	X					X		X				X							F	X		Pu FUELS	PROC. AND/OR FABR. OF FUELS CONTAINING PLUTONIUM
U FUEL R&D			X	X	X		X	X	X					X		X				X								X		U FUEL R&D	RESEARCH AND DEVEL. ON URANIUM FUELS
Pu FUEL R&D			X			X	X	X	X					X		X											F	X		Pu FUEL R&D	RESEARCH AND DEVEL. ON PLUTONIUM FUELS
DEPL. U-METAL			X			X										X		X	F	X		X	X							DEPL. U-METAL	FABR. OF SPECIALITY METAL PARTS FROM DEPLETED URANIUM
DEPL. U-CPDS			X		X											X			X	X			X							DEPL. U-CPDS	PRODN. OF SPECIAL COMPOUNDS CONTAINING DEPLETED URANIUM
COLD U SCRAP					X				F					X	X	X			F	X					X				F	COLD U SCRAP	PROCESSING OF SCRAP CONTAINING UNIRRADIATED URANIUM
COLD Pu SCRAP			F			X			F					X		X				X							F	X		COLD Pu SCRAP	PROCESSING OF SCRAP CONTAINING UNIRRADIATED PLUTONIUM
SPENT FUEL	F								F			F	F								X									SPENT FUEL	REPROCESSING OF IRRADIATED FUEL
SL. ENR. $U \rightarrow UF_6$	F												F								F									SL. ENR. $U \rightarrow UF_6$	CONVERSION TO UF_6 OF URANIUM CONTAINING LESS THAN 5.0% U-235 (FROM OXIDES AND UNH)
HI. ENR. $U \rightarrow UF_6$					X																									HI. ENR. $U \rightarrow UF_6$	CONVERSTION TO UF_6 OF URANIUM CONTAINING MORE THAN 5.0% U-235 (FROM OXIDES AND UNH)
LOCATION OF FACILITY	BARNWELL, S.C.	METROPOLIS, ILL.	CANOGA PARK, CALIF.	LYNCHBURG, VA.	APOLLO, PENN.	LEECHBURG, PENN.	COLUMBUS, OHIO	WINDSOR, CONN.	RICHLAND, WASH.	SAN DIEGO, CALIF.	YOUNGSVILLE, N.C.	SITE NOT YET ANNOUNCED	MORRIS, ILL.	SAN JOSE AND VALLECITOS, CALIF.	WILMINGTON, N.C.	CIMARRON, OKLA.	SEQUOYAH, OKLA.	ALBANY, N.Y.	HUNTSVILLE, TENN.	ERWIN, TENN.	WEST VALLEY, N.Y.	WEST CONCORD, MASS.	JONESBORO, TENN.	ATTLEBORO, MASS.	WOOD RIVER JCT., R.I.	OAK RIDGE, TENN.	ANDERSON, S.C.	CHESWICK, PENN.	COLUMBIA, S.C.	*NOT LIMITED TO COMPANIES THAT ARE COMPETING FOR COMMERCIAL POWER REACTOR RELOADS, BUT INCLUDES SOME COMPANIES WITH LIMITED CAPACITY.	
NAME OF COMPANY	ALLIED GULF NUCLEAR SERVICES	ALLIED CHEMICAL CORPORATION	ATOMICS INTERNATIONAL DIVISION ROCKWELL INTERNATIONAL	THE BABCOCK & WILCOX COMPANY	NUMEC A SUBSIDIARY OF THE BABCOCK & WILCOX COMPANY		BATTELLE MEMORIAL INSTITUTE	COMBUSTION ENGINEERING, INC.	EXXON NUCLEAR CO. AN AFFILIATE OF EXXON CORPORATION	GENERAL ATOMIC COMPANY			GENERAL ELECTRIC COMPANY			KERR-MCGEE CORPORATION		N L INDUSTRIES	NUCLEAR CHEMICALS AND METALS CORP.	NUCLEAR FUEL SERVICES INC. (OWNED BY GETTY-SKELLY OIL COMPANIES)		NUCLEAR METALS DIV. WHITTAKER CORP.	TENNESSEE NUCLEAR SPECIALITIES, INC	TEXAS INSTRUMENTS INCORPORATED	UNITED NUCLEAR CORPORATION	U. S. NUCLEAR	WESTINGHOUSE ELECTRIC CORP			U.S. ATOMIC ENERGY COMMISSION OFFICE OF INDUSTRY RELATIONS. FOR LARGER COPIES TO THIS TABULATION, CONTACT OFFICE OF INDUSTRY RELATIONS.	

FIGURE C-3 TABULATION OF INDUSTRIAL CAPABILITES [AEC-73]

Enrichment Facilities. The enriching of uranium in its U-235 content continues to be the only major step in the nuclear fuel cycle that is not performed by industry as a commercial enterprise. In other words, the AEC is the sole supplier of enriched uranium within the U.S. It operates three enrichment plants with a present capacity of about 17 million SWU per year, which with new, improved equipment is being expanded to about 23 million SWU per year by 1980 and with further expansion will reach a capacity of 28 million SWU per year by 1983. The latter expansion will require additional power supplies of about 1300 MWe which must be obtained from some utility. The AEC has also been engaged in stockpiling as much enriched uranium for future use as possible given the availability of power, uranium, and operating funds [NAE - 74].

However, even with existing U.S. plant production capability increased by virtue of the planned EUP/CIP improvement and uprating programs and with the utilization of the stockpile of enriched uranium produced prior to the mid-1970's, it is projected that additional new enriching capacity will be needed by about 1980 to meet the requirements of areas now served by U.S. plants [AEC - 72].

At this point the Governmental position is that any additional enriching capacity should be provided by private enterprise. Two groups of major U.S. corporations have expressed serious interest in the commercial possibilities of enrichment. Uranium Enrichment Associates -- the consortium made up of Bechtel, Union Carbide, and Westinghouse -- have announced plans to build a $2.75 billion gaseous diffusion enrichment plant in Alabama [WER - 74 - 1]. The proposed facility would require 2400 MWe and would supply approximately 100 nuclear plants (1 GWe) with enriched uranium. General Electric and Exxon Nuclear have announced plans to begin a joint study of the technology and economics of uranium enrichment with primary emphasis on the gas centrifuge process which requires only about 10 percent of the electric power needed in the diffusion process. The advantages of gas diffusion and gas centrifuge can be found in "The Nuclear Industry 1973" [AEC - 73].

Other methods of enrichment are also being investigated; for example, laser enrichment, colliding molecular streams, and chemical separation using specially designed crown compounds that preferentially bond to U-235 are being tested in several laboratories [Nuc. Wk. - 74]. Research on using lasers to separate uranium isotopes has been underway for about one year and is still in an early stage of development. Technical feasibility has not been demonstrated.

Types of Reactors. After more than 30 years of research, development, and large-scale demonstrations, nuclear power plants are presently being utilized on a rapidly increasing scale by electric utilities in the U.S. and the world. Almost all nuclear units in the U.S. are so-called light-water reactors (LWRs), although high temperature gas-cooled reactors (HTGRs) are receiving increasing attention.

Most recent AEC forecasts for nuclear power growth project that under most likely conditions only about 100 GWe of nuclear power will be in operation by the end of 1980, and only about 250 GWe by 1985 [NAE - 74]. This is a downward revision from the 1973 Atomic Industrial Forum study that indicated that 150 GWe could be achieved by 1980 and 365 GWe by 1985 if positive action were taken on certain licensing and other issues [AIF - 73]. Much of this slippage is due to increased bad times which are up from about 6 years in 1968 to 9 to 10 years at the present (Figure C-4).

As of June 1, 1974, 44 nuclear power plants were operating in the U.S. with a total capacity of 27 GWe (see TABLE C-1). Figure C-5 shows the approximate locations of these nuclear plants as well as those that are being built or are on order as of December 31, 1973.

The breeder reactor is still in the developmental stages. The first commercial breeder is not anticipated prior to the late 1980's. The question of whether or not the breeder is really needed in view of the other sources under investigation is an interesting one. The only other long-term alternatives appear to be Solar Energy or Fusion. Sections C-1-3 and C-3 are devoted to brief descriptions of solar energy prospects. Fusion reactors, if proven feasible, probably will not make an impact on total energy production until after 2000 A.D. The uncertainty of fusion and the high capital investment required for solar utilization are the rationale behind the push to Breeders.

Reprocessing. The only currently operating reprocessing facilities in the U.S. are government owned. The limited amount of spent fuel is simply being stored at this time. Three commercially owned and operated facilities are scheduled to become operable during the late 1970's or early 1980's (See Figure C-3). A $270 million nuclear fuel reprocessing plant in Barnwell, South Carolina, is scheduled to begin operation late in 1976 with a capacity of 5 tonnes/day or 1500 tonnes/year assuming 300 operating days per year. This plant can handle the fuel elements from 50 nuclear power plants per year.

Nuclear Fuel Services in West Valley, New York, is now shut down for expansion and plans to reopen with a capacity of 750 tonnes/yr in 1978. The G.E. reprocessing plant in Morris, Illinois, has run into some problems during the testing phase and their plant opening will be delayed at least one and one-half to two years.

Radioactive Waste Management. Radioactive wastes are generated in practically all areas of the nuclear fuel cycle and accumulate as either liquids, solids, or gases at varying radiation levels.

High-level waste, simply described as the concentrated waste materials from the purification stage of a reprocessing plant, are now stored as liquids in large underground tanks. Under AEC's present policy, they must be converted to solid form within five years and shipped to a Federal repository no later than ten years after their separation from the irradiated fuel.

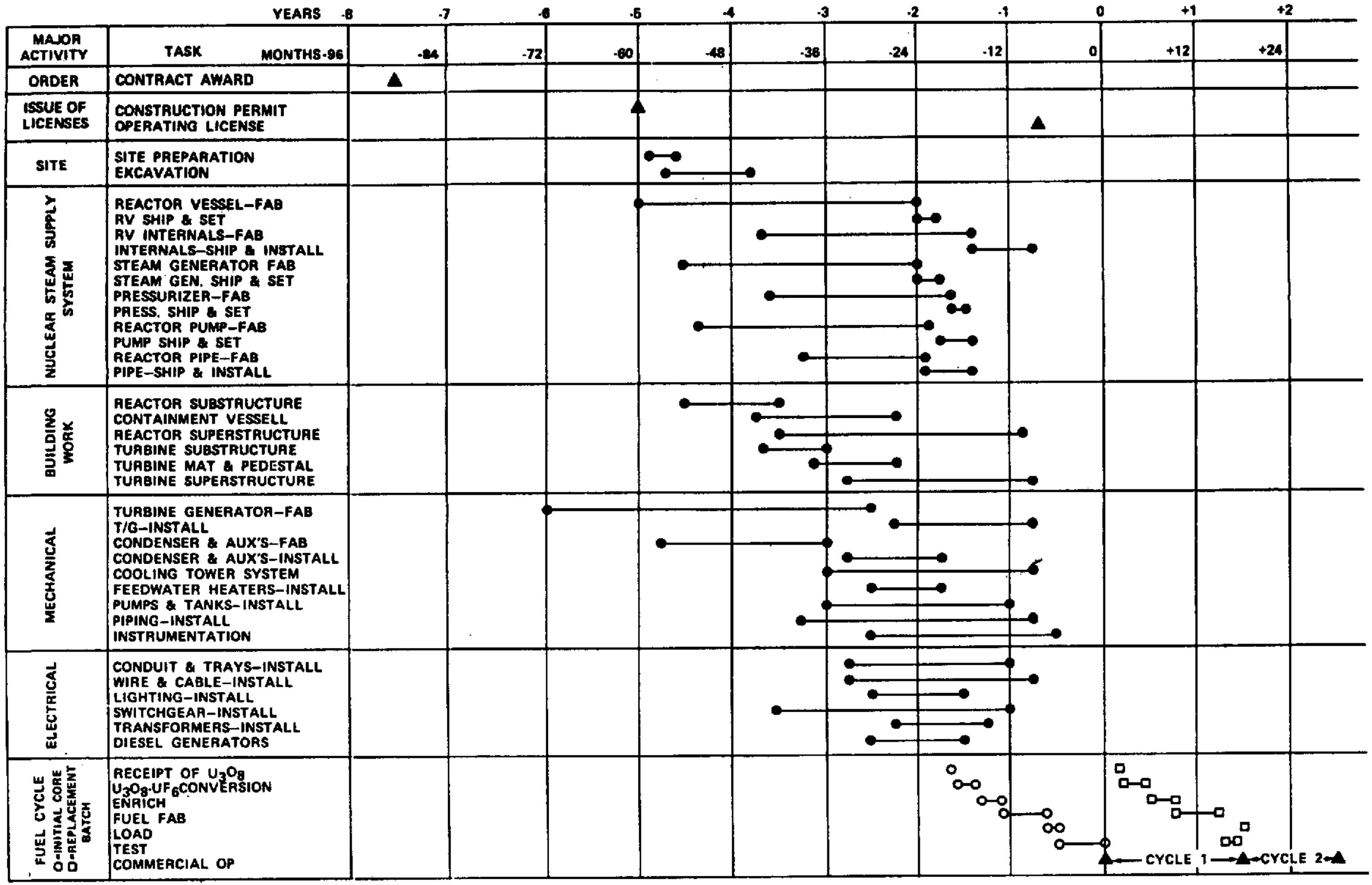


FIGURE C-4 NUCLEAR ELECTRIC POWER PLANT CONSTRUCTION AND OPERATION SCHEDULE

TABLE C-1 REGULATORY STATUS OF NUCLEAR POWER PLANTS AS OF JUNE 1, 1974 [AEC-74-3]

NUMBER			RATED CAPACITY (MWe)
*44	LICENSED TO OPERATE		27,000
**54	CONSTRUCTION PERMIT GRANTED		51,000
	35 UNDER OPERATING LICENSE REVIEW	33,000	
	19 OPERATING LICENSE NOT YET APPLIED FOR	18,000	
62	UNDER CONSTRUCTION PERMIT REVIEW		68,000
	**11 SITE WORK AUTHORIZED, SAFETY REVIEW IN PROCESS	12,000	
	51 SAFETY AND/OR ENVIRONMENTAL REVIEW PROCESS	56,000	
51	ORDERED		57,000
20	PUBLICLY ANNOUNCED		23,000
231	TOTAL		226,000

* IN ADDITION, THERE ARE TWO OPERABLE AEC-OWNED REACTORS WITH COMBINED CAPACITY OF 940 MWe.

** TOTAL OF PLANTS UNDER CONSTRUCTION (CONSTRUCTION PERMIT GRANTED PLUS SITE WORK AUTHORIZED): 65 PLANTS, 63,000 MWe

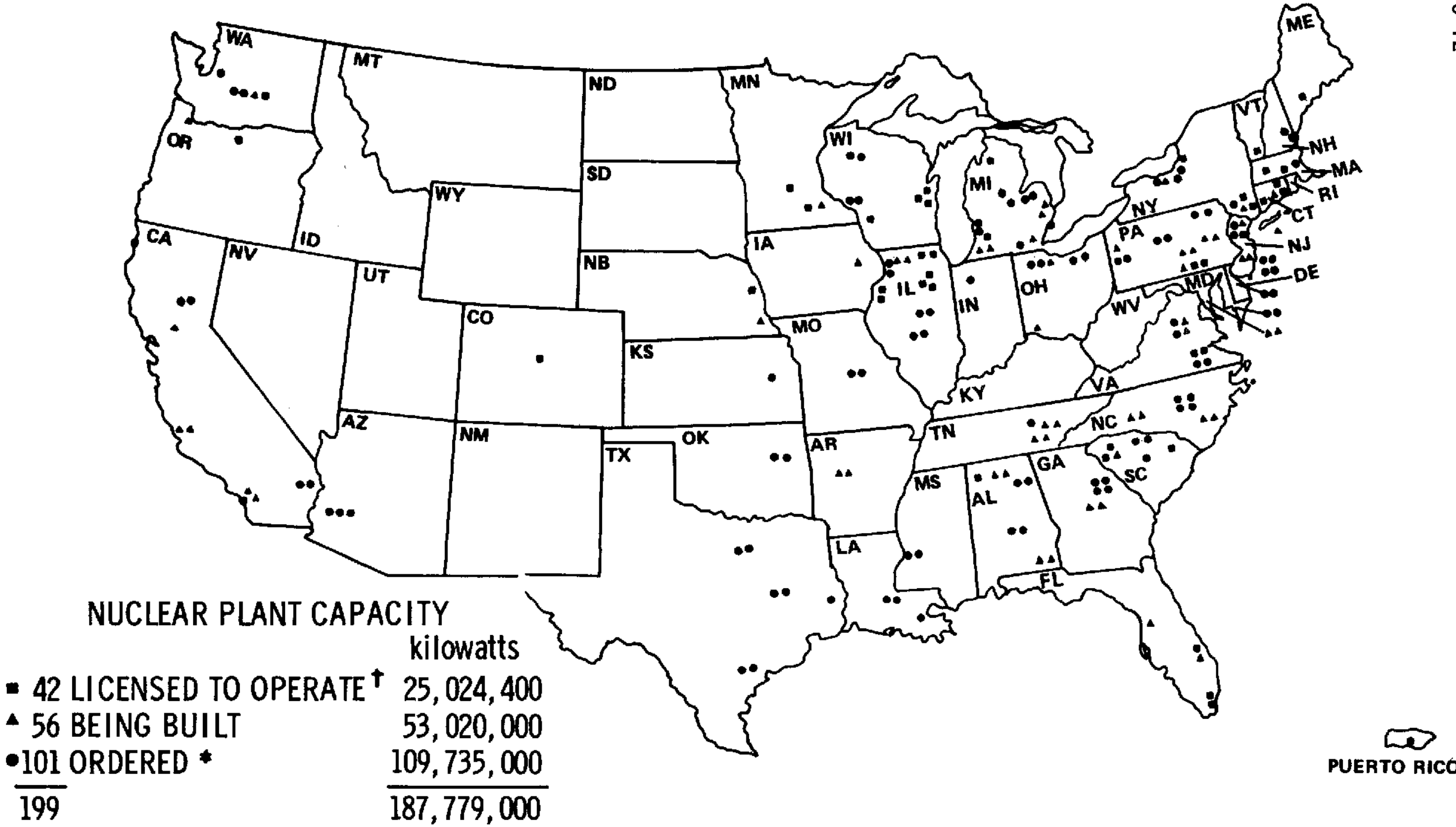


FIGURE C-5 NUCLEAR POWER REACTORS IN THE UNITED STATES [AEC-74-1]

In addition to the high-level wastes defined above, nuclear power plants and industrial operations related to the nuclear fuel cycle, as well as from certain research laboratories and medical and industrial facilities, generate radioactive wastes. Liquid wastes are treated to reduce radioactivity to levels well within established standards, and solid wastes are packaged and shipped to regulated burial sites where they are confined for the period of time for which they may be hazardous if released to the biosphere [AEC - 73].

The predominant means of handling low-level radioactive solid waste in the United States is near surface land burial. Figure C-6 indicates the commercial radioactive waste disposal companies in operation, along with the location of the burial sites in the United States.

Table C-2 shows the quantities of low-level commercial waste buried annually since October 1962. The volumes of low-level solid wastes available annually for commercial burial are estimated to reach about one and one-half million cubic feet in 1973, two million cubic feet in 1975, four million cubic feet in 1980, and six million in 1985, assuming projected growth rate.

Another facet of the radioactive waste business in addition to burial itself, is the operation of collection, packaging, transportation, and storage services [AEC - 73].

Burial of solid radioactive waste generated at AEC sites has been proceeding at a slightly decreasing rate in recent years, from a peak of almost two million cubic feet in 1969 to about 1.4 million cubic feet last year. The AEC supervises a waste management improvement program which places increased emphasis on reducing waste volumes. The total volume of solid waste buried at AEC facilities, during the period 1968 through 1972, is shown in Table C-3. The quantities listed in the table include those wastes that are stored in both a nonretrievable and a retrievable manner. [AEC - 73].

Unit Requirements

Conversion of U_3O_8 to UF_6. As can be seen in Table C-14, the requirements for a facility for converting U_3O_8 to UF_6 are small compared to those of nuclear enrichment facilities and power plants.

Enrichment Facilities. The $2.75 billion gaseous diffusion plant proposed by Uranium Enrichment Associates (UEA) is projected to require about 8000 men at its construction peak. Once it becomes operational 1200 people, of which 250 must be engineers or professionals, will be required to staff the plant. Since 12,000 compressors will be needed in the diffusion plant, a new compressor manufacturing plant will have to be built to meet the demand.

This 9 million SWU/yr plant has slightly higher requirements than

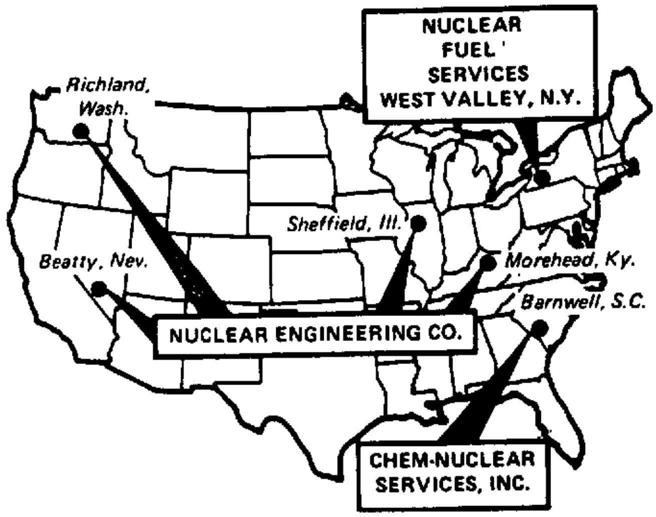


FIGURE C-6. COMMERCIAL BURIAL SITES FOR LOW-LEVEL SOLID WASTE IN U.S. [AEC - 73]

TABLE C-2. PRIVATE WASTE BURIAL [AEC - 73]

Year	Cubic Feet
1962	36,281
1963	214,890
1964	447,094
1965	489,979
1966	502,972
1967	773,850
1968	666,570
1969	750,931
1970	995,099
1971	1,206,800
1972	1,334,542

TABLE C-3

SOLID WASTE BURIED AT AEC FACILITIES [AEC - 73 - 1]

Year	Cubic Feet
1968	1,747,000
1969	1,961,000
1970	1,650,000
1971	1,403,000
1972	1,407,000
1973	1,300,000 (estimated)

those estimated by AEC for a typical 8.75 million SWU/yr plant. The estimated key physical materials and utilities requirements for a typical plant are tabulated in Table C-4 [AEC - 72]. The construction schedule for this typical plant is shown in Figure C-7.

The construction of a gaseous diffusion plant can be conveniently broken down into two phases: the first phase includes site work, construction of utilities, services, warehouses, and component assembly buildings, and construction of the process buildings themselves; the second phase consists of the assembly, installation, and start-up of the process equipment. These phases can overlap to some extent as shown in Figure C-7.

The first phase scheduling is determined by balancing the high interest costs of having capital invested in an unproductive set over a long period of time against the costs of inefficiencies resulting from a work force so large that it cannot be used effectively. Large or sharp peaks of construction labor in general or sharp peaks in any crafts in particular are undesirable. [AEC - 72]

The rates of delivery of process stage components sets the construction schedule for the second phase. The optimum rate for the second phase of construction is set by balancing, for example, tooling costs for special manufacturing facilities against the cost of interest during construction. The criteria for setting the construction time shown in Figure C-7 include the desire to put the plant on stream in a timely fashion without resorting to a crash program, and judgments concerning the production capabilities of component suppliers. As can be seen in Figure C-7, it is expected that an 8.75 million SWU/yr plant can be built in about six years. However, the equivalent full production date occurs only 4.75 years after start of construction because of the separative work produced during the construction period. [AEC - 72]

A representative breakdown of the personnel requirements (somewhat lower than those projected for the UEA plant) is presented in Table C-5 for the case of the 8.75 million SWU/yr plant. About 10 percent of the personnel will be professional (engineers, accountants, management specialists, supervision, etc.). Assuming that the personnel have had no previous experience in diffusion plant operations, 50 percent of the manpower must have some special on-the-job training before undertaking plant assignments [AEC - 72].

The enrichment facility requirements will be summarized in Table C-14.

Types of Reactors. Considering the fact that many people feel that nuclear energy will supply as much as 60 percent of the total electricity produced in the year 2000 because it is cheaper and cleaner than electricity from fossil fuel plants, the need to determine the requirements for various types of reactors becomes evident. The manpower, materials, and capital requirements for typical LWR and HTGRs are discussed in this section.

TABLE C-4 ESTIMATED KEY PHYSICAL, MATERIALS, AND UTILITIES REQUIREMENTS FOR AN 8.75 MILLION SWU/YR NEW PLANT UTILIZING L(&) TECHNOLOGY [AEC-72]

Requirement	Item	Quantity
Physical	Plant Ground Coverage	300 acres
	Process Buildings Ground Coverage	50 acres
	Process Support Facilities	25 acres
	Feed, Product, and Waste Storage	7 acres
	Soil Bearing Requirement	2,500 psf on spread-type footings
Construction	Concrete	300,000 cu yd
Materials	Reinforcing Steel	10,000 tons
	Structural Steel	60,000 tons
	Process Steel Pipe	15,000 tons
	Auxiliary Systems Pipe	10,000 tons
	Organic Coolant	1,500 tons
Utilities	Electric Power	2,430 Mw
Capacities	Water Supply	20,000,000 gpd
	Dry Air	12,000 scfm
	Steam	350,000 lb/hr

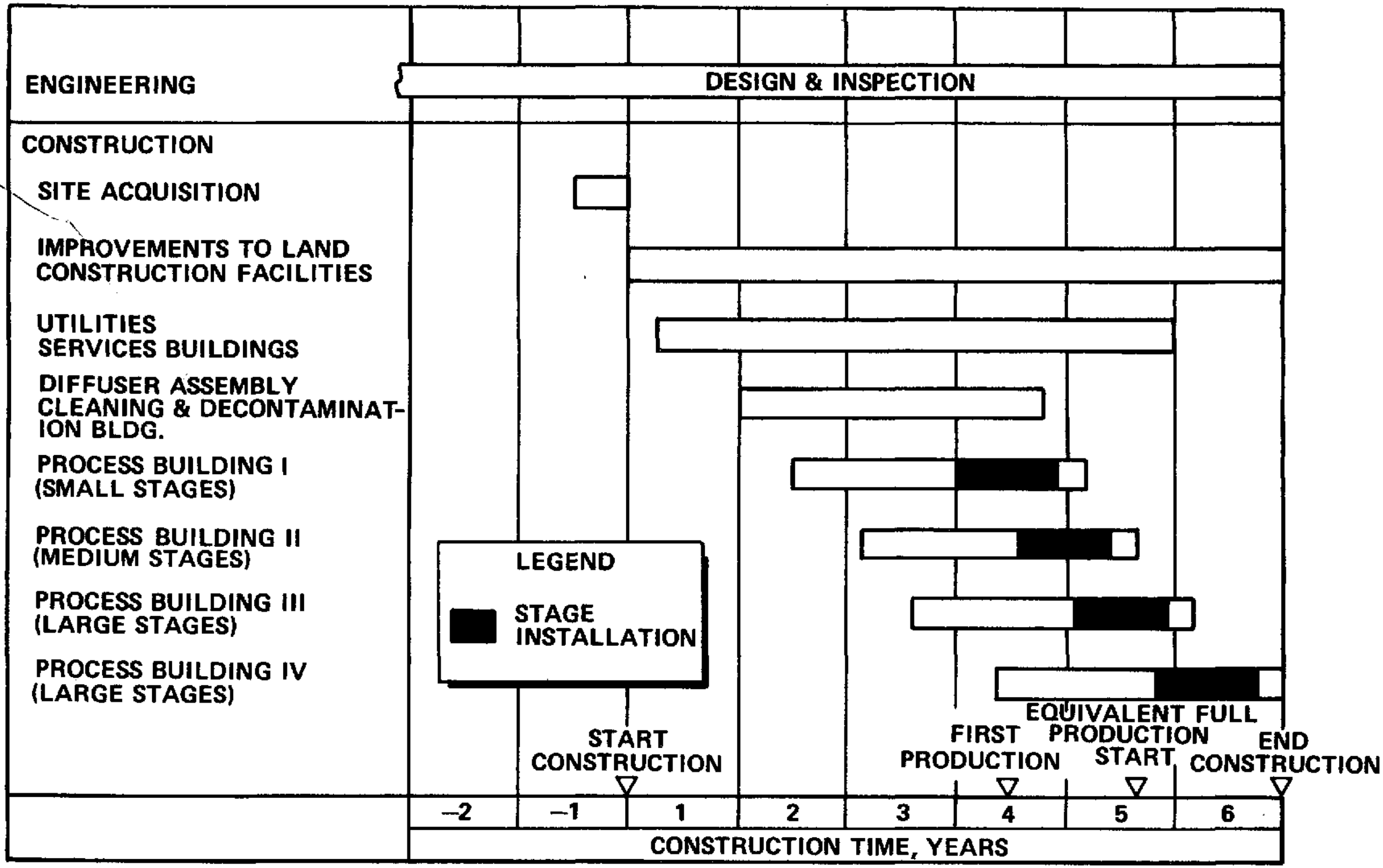


FIGURE C-7 CONSTRUCTION SCHEDULE FOR AN 8.75 MILLION-SWU/YR GASEOUS DIFFUSION PLANT

TABLE C-5 PERSONNEL BREAKDOWN FOR AN 8.75 MILLION SWU/YR PLANT (1970 Technology) [AEC-72]

Plant Superintendent and Staff	6
Operations	
Central Control Room	8
Shift Superintendent	5
Process Operations	164
Process Engineering	12
Laboratory	27
Fire and Guards	44
Utilities	60
Plant Engineering	28
Finance and Materials	113
Industrial Relations	22
Maintenance	
Services	104
Field Crews	207
Maintenance Engineering	12
Shops	88
TOTAL	900

Manpower: A general rule-of-thumb figure used to calculate manhours of construction manpower is 8 and one-half to 11 manhours per KWe of plant capacity. Engineering manpower data ranged from 1.18 to 1.89 engineering manhours/KWe with an upward trend toward numbers higher than the 1.4 manhours/KWe suggested by the AEC [Budwani - 74].

The manpower requirements for the manufacture of an offshore FNP are broken down in Table C-6. These people will all work in FNP's at the Westinghouse Blount Island Facility which is now under construction. This facility, which will require a work force of approximately 2000 at its peak, is expected to manufacture 4 FNP's per year. Obviously, fewer people are required in this process than are required in the construction of a land-based nuclear plant. [Musselman - 74]

Considering the rate of growth of nuclear power plants projected by various sectors, the necessity for anticipating and resolving problem areas that could curtail the nuclear power program becomes obvious. In fact, the ability to expand the energy industry will depend heavily upon the numbers, qualifications, and capabilities of engineers, designers, technicians, and project managers as well as skilled craftsmen. Utilities are already experiencing difficulties in manning the engineering and production staffs of their nuclear power plants and the situation is expected to get worse in the future. [Wilson - 74].

If we take the engineering field as an example, W. E. Wilson conducted a survey to determine the number of engineers hired by the various sectors of the nuclear power industry. There are four basic segments of the nuclear power industry: the nuclear fuel processing group, the nuclear steam supply system (NSSS) design and fabrication group, the architect-engineer group, and the nuclear utility group. The total number of engineers of all types hired by the 31 firms (approximately 20 percent of the nuclear power industry) that answered Wilson's survey are summarized in Table C-7.

Extending the 19.6 percent employment expansion rate over the next three years means a total annual requirement of 1,140 nuclear-oriented engineers per year in the nuclear power industry, as can be seen in Table C-7. This number is somewhat lower than that obtained in the Deutsch and Whitney study of nuclear manpower. However, whereas Deutsch and Whitney included the engineering manpower required during the construction of the power plant, Wilson does not make any statement as to when the manpower needs begin. The focus of the Deutsch and Whitney study was the components of the overall manpower structure that are directly involved in the design, licensing, construction, and operation of nuclear power plants. [Deutsch - 74]

TABLE C-6 APPROXIMATE DISTRIBUTION OF CRAFT SKILLS
1975 - 1981
FNP MANUFACTURE [Musselman - 74]

Operators, Riggers & Drivers	7.5%	760
Carpenters	5.5%	540
Cleaners - Painters	8%	800
N.D.T. Technicians	3%	300
Machinists	1.5%	160
Clerks	2%	200
Laborers	11.4%	1140
Welders, Burners, Operators	8.5%	840
Steel Fabricators, Operators	6%	600
Millwrights - Erectors	9.5%	960
Sheetmetal Fabricators	5%	500
Electricians	5%	500
Electronic Technicians	3%	300
Concrete Workers	0.2%	20
Iron Workers	2%	200
Analysts - Expeditors	1.5%	160
Pipe Fitters	8.5%	840
Foreman - Supervisors	11.9%	1180
	100%	10,000

TABLE C-7 SUMMARY OF NUCLEAR POWER INDUSTRY

EMPLOYMENT DATA[†] (Wilson - 74)

Discipline	Degree	Current Employment	Employment Increase* Annual Number	Employment Increase* Percent
N.E.	BS	455	102.3	22.5
	MS	406	91.5	22.5
	Total	861	193.8	22.5
Ch.E.	BS	554	79.0	14.3
	MS	140	45.0	32.1
	Total	694	124.0	17.9
M.E.	BS	1,647	267.9	16.3
	MS	422	82.3	19.5
	Total	2,069	350.2	16.9
E.E.	BS	1,094	136.7	12.5
	MS	164	28.9	17.6
	Total	1,258	165.6	13.2
C.E.	BS	422	73.4	17.4
	MS	104	28.1	27.0
	Total	526	101.5	19.3
Q.C.E.[a]	BS	185	47.1	25.4
	MS	50	23.0	46.1
	Total	235	70.1	29.8
R.L.E.[b]	BS	62	32.9	53.1
	MS	34	12.1	35.6
	Total	96	45.0	46.9
E.S.[c]	BS	53	45.6	86.0
	MS	29	16.3	56.2
	Total	82	61.9	75.5
Totals	BS	4,472	813	18.2
	MS	1,349	327	24.2
	Grand	5,821	1,140	19.6

*Average over period from 1973 to 1975.

[a]Quality control engineer.

[b]Reactor licensing engineer.

[c]Environmental specialist.

[†]Thirty-one companies responding, whose numbers of engineers employed (see totals above) represent approximately 20 percent of the entire nuclear industry.

The overall schedule for design, licensing, construction, and operation of a nuclear power plant has a critical effect on manpower requirements because this schedule determines when personnel must be assigned to a particular nuclear power plant project. This schedule (Figure C-4) indicates that it takes almost 10 years from site selection to commercial operation. However, it is believed that this lead time can be substantially reduced by standardization of plant design, early site approval, and coordination of the National Policy Act.

The staffing schedules for the design, licensing, construction, and operation of a nuclear power plant is defined in the Deutsch and Whitney study using the results of a questionnaire sent to several utilities with nuclear power plant experience and discussions with several other utilities and with several architect-engineers. In all cases the reference was a single unit 1.1 GWe nuclear power plant [Deutsch - 74].

Although the size of nuclear utility staffs vary somewhat, a typical single unit 1.1 GWe nuclear power plant staff used by Deutsch and Whitney is presented in Table C-8. The overall composition of a typical plant staff of 75 is 15 engineers and 60 non-engineers, where an engineer is defined as an individual with a four-year engineering degree or experience equivalent to such a degree. In addition, about 25 utility personnel -- 15 engineers and 10 non-engineers -- are required to provide support services after the plant goes into operation. [Deutsch - 74]

Table C-9 includes the typical staffing schedule for the utility's operations staff and its engineering and technical support staff (more difficult to define) for a single unit 1.1 GWe nuclear power plant. The number of engineers and non-engineers required on each staff is given by year. As indicated in Table C-9, a total of 285 man-years from the operations staff and 275 man-years from the engineering and technical support staff is required prior to commercial operation. After commercial operation, a total of 75 man-years per year and 25 man-years per year, respectively, are required for these two staffs. Although there should be significant savings for multiple units on the same site, the Deutsch and Whitney study used single unit staffing for reasons discussed in their article [Deutsch - 74].

Since the manpower requirements of nuclear utilities alone are but a small part of the total picture, the requirements of other organizations, such as architect-engineers, nuclear steam supply vendors, technical consultants, construction management organizations, suppliers and other organizations, must also be estimated. The typical staffing schedules for each of the organizations that provide direct support for the design, licensing, construction and operation of a nuclear power plant is included in Table C-9.

TABLE C-8 TYPICAL NUCLEAR UTILITY OPERATIONS STAFF [Deutsch - 74]

(Single Unit 100 Mw Nuclear Power Plant)

Plant Superintendent	1
Assistant Plant Superintendent	1
Operations Supervisor	1
Training Coordinator	1
Shift Supervisors (SRO Licenses)	6
Control Operators (RO Licenses)	12
Auxiliary Operators	12
Technical Supervisor	1
Technical Staff	8
Technicians	12
Maintenance Supervisor	1
Electrical and Mechanical Maintenance Personnel	19
Total	75

TABLE C-9 COMBINED NUCLEAR UTILITY AND DIRECT SUPPORT STAFFING SCHEDULES [Deutsch - 74]

(Single Unit, 1100 Mw Nuclear Power Plant)

Year	Utility		Direct Support Organizations				
	Operations Staff (Engineers/Non-Engineers)	Engineering and Technical Support Staff (Engineers/Non-Engineers)	Architect Engineer (Engineers/Non-Engineers)	Nuclear Steam Supply System Vendor (Engineers/Non-Engineers)	Technical Consultants (Engineers/Non-Engineers)	Construction Management Organization (Engineers/Non-Engineers)	Total (Engineers/Non-Engineers)
1	0/0	10/0	10/5	5/0	10/0	0/0	35/5
2	0/0	10/0	10/10	10/0	10/0	0/0	40/10
3	0/0	15/5	25/25	15/5	15/0	0/0	70/35
4	0/0	20/5	50/50	15/5	15/0	10/0	110/60
5	0/0	25/10	70/70	15/5	20/0	10/30	140/115
6	5/0	25/10	75/70	15/5	20/0	20/60	160/145
7	15/40	25/10	55/55	15/5	20/0	20/60	150/170
8	15/60	25/10	50/50	15/5	20/0	20/60	145/185
9	15/60	25/10	25/25	10/0	10/0	10/30	95/125
10	15/60	25/10	15/5	5/0	5/0	10/0	75/75
Total Man-Years Prior to Commercial Operation	65/220	205/70	385/365	120/30	145/0	100/240	1,020/925
Man-Years Per Year After Commercial Operation	15/60	15/10	Not Estimated	Not Estimated	Not Estimated	Not Estimated	30/70

The total staffing requirement for a nuclear power plant is obtained by combining the staffing schedules for the utility with that for the direct support organizations. As shown in Table C-9, a total of 1,945 man-years prior to commercial operation and a total of 100 man-years per year after commercial operations are required per plant. The assumption that additional support from other organizations ceases after commercial operation makes the results of the study conservative even though their results are consistently greater than those obtained by the AEC study [AEC - 73 - 1]. Some of the other areas that compete for these engineers and technicians are companies that manufacture radiation detection and monitoring devices and other instruments for the nuclear energy field, companies which specialize in the manufacture of particle accelerators, and industries that process and package and dispose of radioactive wastes and perform radiography services for non-nuclear industries.

One area of concern in the manpower question is simply how many engineers are currently being graduated? In 1970-71, the 65 institutions having nuclear programs graduated 956 nuclear-oriented engineers (399 BS, 387 MS, and 170 Ph.D). Eliminating the 18 percent of BS students who enter full-time graduate study and the foreign students who return home yields approximately 800 nuclear-oriented engineering graduates per year. [Wilson - 74] If engineering degrees in all fields are considered, the annual survey of the Engineering Manpower Commission of the Engineers Joint Council showed that the number of four-year engineering degrees granted in the U.S. in the year ending June 30, 1973 declined to 43,429 BS, 17,152 MS, and 3,587 Ph.D, down from 44,190, 17,356, and 3,774, respectively, for 1972. [Deutsch - 74] The number of two-year associate degrees in engineering technology also declined for the year ending June 30, 1973, to 9,040, down from 9,084 in 1972. The number of engineers that received BS and MS degrees in nuclear engineering in the same year was 324 and 387, respectively. [Deutsch - 74]

Materials and capital: Tables C-10, C-11, and C-12 give the estimated requirements for building a LWR, HTGR, and a floating nuclear plant (FNP). These requirements will be tabulated in Table C-14.

CANDU: The Canadians are active in the world-wide reactor market. Their product is attractive because no enrichment is required. The local utility can make its own fuel from U_3O_8, which is especially attractive to countries like India, Pakistan, and S. Korea where human labor is abundant and foreign exchange capital scarce. A calandria, used instead of a heavy reactor vessel, is like a heat exchanger, with pressurized tubes holding the fuel elements with D_2O moderator at lower pressure in the shell.

TABLE C-10 MATERIALS FOR A 1.1 GWe LWR [Budwani - 74]

Capital Costs	$444 million*
Concrete	$1.0 - 1.5 \times 10^5$ yd^3
Structural Steel	$3.0 - 6.0 \times 10^3$ tons
Piping	$2.5 - 3.5 \times 10^5$ LF
Power & control cables	$2.5 - 4.0 \times 10^6$ LF
Conduits	$3.3 - 5.5 \times 10^5$ LF
Power & control terminations	$9.0 - 12.5 \times 10^4$

*[AEC - 73 - 1] uses 1973 dollars for a 1.0 GWe LWR and includes interest during construction (7 percent/yr) assuming a construction schedule of 7 and one-half years. If escalation during construction were included an additional $100 million would have to be added to give a grand total of $544 million.

TABLE C-11 REQUIREMENTS FOR A HIGH TEMPERATURE GAS-COOLED REACTOR (HTGR) 1.3GWe

Capital Cost	444 million (1973 dollars)
Land	400 acres
Concrete	9.0×10^5 yd^3
Steel	1.5×10^4 tons
Manpower*	$9.5 - 11.0 \times 10^6$ man hrs

*estimated at 9.5 - 11 man hrs/KWe

TABLE C-12 REQUIREMENTS FOR A FLOATING NUCLEAR PLANT (FNP)

Capital Cost	$400 Million
Water	70-90 acres of ocean (not including cooling water)
Concrete	38,000 yd^3
Steel	32,000 tons
Manpower	7 x 10^6 man hrs.

Refueling while running at full power can improve the utilization factor by 10 percent. The control rods, primary loop equipment, and refueling operations are all controlled by a pair of digital computers. Also, the CANDU reactor gets about 1 percent of the potential energy in uranium comparable to that obtained in light water reactors with fuel recycling. If breeders are never used extensively, the possibility of eliminating the reprocessing plant from the cycle by disposing of the spent fuel intact appears attractive. (The present Canadian design has a large holding pool beside the reactor; they don't know whether the spent fuel will prove to be a liability or an asset.) The Canadians now have D_2O production facilities of 1000 Tonnes/yr, and plan to expand to 4500 Tonnes/yr^2 by 1981. [NEI - 74]

Breeders: The U.S. has been researching LMFBR's since the early 1950's. Currently U.S.A.E.C. is designing the Clinch River 400 MWe demonstration plant to be built in southern Tennessee. This plant will be built with many of the components designed for the Fast Flux Test Facility nearing completion near Hanford, Washington. If all goes well, the Clinch River LMFBR will be completed by 1981, at a cost of about $600,000,000. France recently (April, 1974) brought its "Phenix" LMFBR to full power of 250 MWe. U.S.S.R., West Germany, and England also have hundred-megawatt-size LMFBR's. There are other types of breeders in the conceptual design and pilot plant stages: molten salt breeders and gas-cooled fast breeders. However, it is probably significant that all the countries that have undertaken breeder research have put most of their money on the LMFBR as the concept most likely to succeed. Optimistically, it will be 1990 before LMFBR's can compete commercially. [PBRC - 74]

Finally, Rickover's Light Water 'Breeder' deserves a few comments. There is some doubt whether it will be a true breeder, in the sense that it produces more fuel than it consumes; but it will be a very good converter. In a converter, the initial charge of fuel is multiplied by

$$U = U_0(1/1-x)$$

where x is the conversion ratio. A good converter ($x \approx 0.95$) can multiply the fuel resources by a factor of 20; consequently the U-235 or Pu-239 required to operate a 'Light Breeder Reactor' (LBR) is a small fraction of that required for a PWR or BWR. However, the LBR needs support facilities to process thorium: mines, mills, fuel fabrication, and reprocessing. Therefore, it will probably be economically attractive only after uranium becomes scarce and existing industries make plans to convert to thorium as a fuel.

Reprocessing. Approximately a ten year lead time is required to construct and test a reprocessing plant. Many of the same restrictions for siting apply to reprocessing plants that apply to nuclear power plants. Requirements for the Barnwell Nuclear Fuel Plant owned by Allied - Gulf Nuclear Services include about 60,000 yd^3 of concrete, 6,000 tons of steel, skilled manpower similar to that for a nuclear power plant, $270 million for construction, and about 350 operating personnel (see Table C-14).

Radioactive Wastes. The gaseous, liquid, and solid radioactive wastes generated during operation of water-cooled nuclear power plants must be collected, treated, and ultimately buried, or stored for release to the environment under controlled conditions. Gaseous wastes, such as xenon, krypton, and tritium are handled separately as gases.

Liquid wastes include the waste streams from drains, laundry, laboratory decontamination, etc., within the plant. After treatment -- filtration, ion exchange, neutralization, and concentration -- these waste streams are either returned to one of the reactor water systems or discharged to the surface water. The evaporator concentrates are processed through the solid radwaste system for burial.

If feasible, dry wastes are collected and compressed for storage in 55 gallon drums and ultimate burial. After mixing with cement or other immobilizing materials, the wet solids are drummed and stored for burial. Table C-13 summarizes the annual waste generated by LWRs.

High-level wastes in excess of five years in inventory must be converted to an AEC-approved form (not yet selected) and shipped to a Federal repository no later than ten years after their separation from irradiated fuels. The government will assume physical responsibility for these radioactive materials and must charge a fee to cover the cost of disposal and perpetual surveillance. High-level waste will not begin to arrive until after 1983 because the wastes will be cooled for up to ten years at the spent fuels reprocessing plants. A typical canister, 72" in diameter by 10' long, will contain 10 percent of a 1.0 GWe reactor [AEC - 73].

The AEC intends to construct a RSSF (Retrievable Surface Storage Facility), which is thought to be reliable as long as man continues to provide the necessary surveillance and maintenance. The water basin concept, selected as a reference design, is leased on the design and operation of storage pools used for the past 30 years for the storage of radioactive heat producing material. The facility is a steel and reinforced concrete complex at ground surface, consisting of three major elements: (1) the waste receiving and handling facility, (2) the storage facility, a series of water filled reinforced concrete basins, and (3) heat rejection facilities from which the waste heat from each basin will be dissipated to the atmosphere. The water provides both the cooling medium and the shielding. [AEC - 73]

Two air-cooled concepts are being evaluated. The air-cooled vault

TABLE C-13 SOLID WASTES FROM 1.0 GWe LWR ANNUALLY [AEC - 73]

	BWR	PWR
3899 ft^3 significant radioactive wastes	X	
1000 ft^3 " " "		X
2150 drums* (55 gallon)	X	
600 drums " "		X
30 - 50 drums compacted dry solid wastes	X	X

*Typically, waste material is immobilized in cement or other materials at an estimated ratio of 1.8 ft^3 of waste to 5.4 ft^3 of cement in a 7.2 ft^3 drum.

uses circulation of air around the cannister and a wide separation between them to replace the water needed for cooling. The shielding provided by the water can be replaced by special attention to handling, emplacement, and extra concrete. Another air-cooled concept being evaluated employs a wide spacing between cannisters to eliminate the need for cooling water (Figure C-8). Shielding is provided by thick steel and concrete shrouds.

Still under evaluation is the Bedded Salt Pilot Plant (BSPP) Concept which is a non-retrievable form of storage. The BSPP program is designed to confirm analytical studies, establish waste shipping and handling techniques, and to gain public acceptance. A limited number of fully retrievable waste cannisters could be used to verify the results of laboratory experiments and analytical predictions. In this way, if public acceptance is not obtained or if something goes wrong, the waste could be retrieved and put in the RSSF. [AEC - 73].

Other concepts under investigation include disposal in geological formations other than salt, disposal in space, polar ice caps, ocean trenches, etc.

Estimates of the manpower, materials, land area, capital, and power requirements to build and operate the various facilities in the nuclear fuel cycle are summarized in TABLE C-14.

Path Requirement

The path requirements for the Nuclear Electric Economy (NEE), the Ford Technical Fix - Base Case (FTFB), and the alternate path to the Ford Technical Fix future (AFTF) are discussed in this section. The values given below for the gigawatts of nuclear power required in each scenario were derived from Table 7-3:

1973 - 25	1990 - 588
1975 - 50	1995 - 956
1980 - 123	2000 - 1400
1985 - 306	

A smooth curve was used to determine the gigawatts of power needed each year. These numbers were reduced to the number of power plants required each year by assuming power plants built until 1980 would be 1.1 GWe plants and those after 1980 would be 1.3 GWe plants. This kind of procedure means that the two and three units per power plant that are becoming more common were not considered due to the limited amount of time and manpower available for the computations. However, this kind of parameter could easily be included in additional computations.

Although lower numbers than those projected by AEC were used for the number of power plants becoming operable in the next three or four years, the building pace accelerated each year so that after 1980 the number of plants that must become operable each year is greater than predicted by AEC. Because of the 10 year lead time involved in building and licensing a nuclear power plant, plans for those plants that must

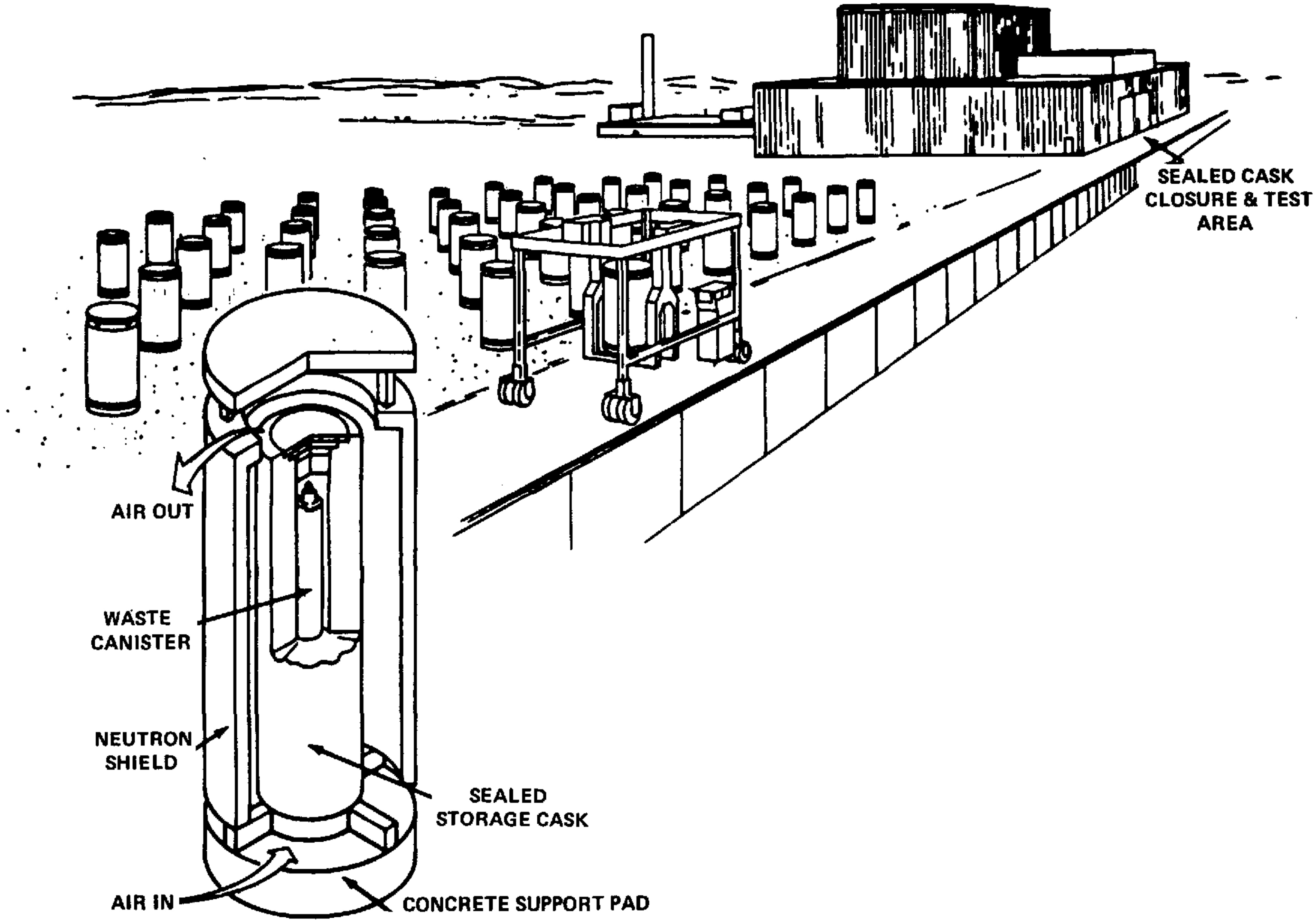


FIGURE C-8 AIR-COOLED RETRIEVAL SURFACE STORAGE FACILITY [AEC-73-1]

Process	Construction Designers (10^6 man hrs)	Craftsmen	Leadtime (yrs)	Steel (tons)	Concrete (yd^3)	Special Equipment
U_3O_8 Conversion (9000 tonnes/yr)	1	2	4	-	-	Monel Tanks
Gas Diffusion Enrichment (8.75×10^6 SWU/yr)	?	24.	6	7×10^4	3×10^5	Compressors
Centrifuge Enrichment (8.75×10^6 SWU/yr)	?	?	8	-	-	Large High Speed Centrifuges
UO_2 Fuel Fabrication (1200 Tonnes/yr)	1	2	6	-	-	Machine Tools
Mixed Oxide Fuel Fabrication (250 Tonnes/yr)	1.5	4	7	-	-	Glove Boxes
D_2O Plant (800 Tonnes/yr)	-	-	5	-	-	Large Reaction Vessels
Floating Pwr (2000 MWe)	0.5	7.0	4	3.2×10^4	3.8×10^4	Special Burge
BWR (3 units) 1152 MWe ea.	3.5	27.0	10	2.67×10^4	2.7×10^5	Vessel, Heat Exchanger Turbines, Generators, Pumps
HTGCR (770 Mwe)	?	8.5	9	?	?	Prestressed Concrete Vessel
CANDU (4 units) 514 MWe ea.	?	?	6	?	?	480 Tonnes D_2O
LMFBR (400 MWe)	6	4	8	-	-	Sodium Circulation
LBR	?	1 (refit)	2	-	-	Beryllium
Fuel Reprocessing Plant (1500 Tonnes/yr)	Comparable to Power Plant		9	6×10^4	6×10^3	Monel, Stainless Steel
Waste 'Mausoleum' (entire U.S.)	2	1	5	?	?	

(- means probably negligible, ? means maybe important but not yet available)

TABLE C-14 UNIT REQUIREMENTS FOR NUCLEAR FACILITIES (CONT)

Process	Capital ($ Million)	Land Area (acres)	Operating Personnel	Power (MW)	H_2O (gpd)	Effluents
U_3O_8 Conversion (9000 Tonnes/yr)	$ 37	80	50	-	-	Ru^{226}, Th^{230} Pu^{231}
Gas Diffusion Enrichment (8.75×10^6 SWU/yr)	1200*	400	900	2430	2×10^7	U
Centrifuge Enrichment (8.75×10^6 SWU/yr)	1420	300	2000	240	-	U
UO_2 Fuel Fabrication (1200 Tonnes/yr)	50	100	1200	-	-	?
Mixed Oxide Fuel Fabrication (250 Tonnes/yr)	50	100	600	-	-	Pu
D_2O Plant (800 Tonnes/yr)	200	2000	?	50 MWe 200 MWt	-	H_2S
Floating PWR (2000 MWe)	400	90	125	-	seawater	Waste Heat
BWR (3 units) 1152 MWe ea.	1180	920	190	-	2.5×10^9	Waste Heat
HTGCR (770 MWe)	263	400	77	-	-	
CANDU (4 units) 514 MWe ea.	746	1000	150	-	-	H^3
LMFBR (400 MWe)	600	-	?	-	-	Na^{24}
LBR	?	-	80	-	-	
Fuel Reprocessing Plant (1500 Tonnes/yr)	270	1000	350	-	-	Kr^{85}, H^3 Actinides
Waste 'Mausoleum' (entire U.S.)	2000 (Includes Shipping)	6400	100	-	-	Sr^{90}, Cs^{131} Pr^{147}, I^{129} Sm^{151}, Tc^{99}

(- means probably negligible, ? means maybe important but not yet available)

* $2.75 billion UEA plant is considerably higher cost estimate.

be operable in 1984 must be underway in 1974. Assuming that these lead times are not reduced within the next ten years, a comparison of the number of plants projected to be operable in 1984 by AEC (24) to the number needed by the NEE scenario (33) gives an indication of the magnitude of the task set forth by this path of action.

A summary of the method used to calculate the construction force is presented below.

The construction phase was assumed to cover the last five years of the ten-year lead time. Consequently, a number of plants would be in each of the five years of construction. For example, in 1986, 39 plants would be in the final year of construction, 42 in the 9th, 45 in the 8th, 48 in the 7th, and 50 in the 6th; thus a total of 224 plants would be in some phase of construction. According to most recent estimates, a figure of 8.5 - 11 man-hr/Kw is a reasonable number to use to calculate the number of people involved in the construction of the plant. Therefore a 1.0 GWe plant would require 10 million man-hours during construction if the 10 man-hr/Kw figure is used. Spreading this requirement out evenly over the five year period gives 2 million man-hours per gigawatt per year. Even though this distribution of manpower is admittedly incorrect (a peak exists in the manpower curve), the assumption appears to be valid in view of the number of plants that must simultaneously be under construction. Therefore, the number of people involved in the construction of 224 (1.3 GWe) plants in 1986, assuming a 2080 hours to years conversion (this is probably low due to overtime), is 2.80×10^5. Based on current breakdown of the workforce, the assumption was made that about 13 percent of this construction population be engineers.

Considering the magnitude of the number of people involved in staffing the nuclear power plants and the support systems required for the construction of these plants [Deutsch - 74], the staffing personnel -- engineers and non-engineers -- required each year was calculated and the sums for each five year interval was tabulated and added to the construction manpower numbers. This total appears in Table C-15.

In the case of enrichment facilities, construction of one plant per year until 2000 A.D. should provide sufficient enriching facilities for the projected growth in nuclear power plants. In order to obtain estimated manpower requirements, a work force curve [AEC - 72] was integrated. Using this number and the number of plants under construction in a specified year gave the estimated number of people involved in construction of the enrichment facilities for that year. These manpower figures also appear in Table C-15. About 4 percent of the work force was assumed to be engineers. The staffing requirements in this case include only the people involved in the operation and maintenance of the enrichment plant (900/plant). The number appearing in Table C-15 was obtained by multiplying the number of enrichment facilities operating in that year by 900 persons per plant assuming about 7 percent of the operating personnel will be engineers.

It was assumed that the construction crews for reprocessing plants

TABLE C-15 NEE - PATH REQUIREMENTS

	Manpower Engineers	Manpower Non-engineers	Capital	Steel (tons)	Concrete (yd^3)
Nuclear Reactor Power Plants					
1973	2.2×10^4	6.4×10^4	\$ 5.4×10^9	9.3×10^4	3.1×10^5
1980	5.0×10^4	1.5×10^5	\$ 53.5×10^9	1.3×10^6	5.5×10^6
1985	8.7	2.9	93.5	2.1	2.1×10^7
1990	11.9	3.9	131.1	3.1	3.4
1995	1.5	5.0	164.4	3.8	4.6
2000	1.7	5.7	191.6	4.2	5.1
Enrichment Plants					
1980	1.0×10^3	2.4×10^4	\$ 0.9×10^9	1.8×10^5	7.5×10^5
1985	1.5	3.4	5.7	4.4	1.9×10^6
1990	1.8	3.9	6.0	4.8	2.0
1995	2.1	4.3	6.0	4.8	2.0
2000	2.4	4.7	6.0	4.8	2.0
Reprocessing Plants					
1980	8.2×10^2	5.6×10^3	\$ 0.7×10^9	1.4×10^5	1.4×10^4
1985	1.7×10^3	1.7×10^4	2.6	4.6	4.6
1990	2.5	1.8	2.7	6.0	6.0
1995	3.1	2.4	4.1	9.0	9.0
2000	3.6	2.8	4.1	10.0	10.0
$U_3O_8 \rightarrow UF_6$, Fabrication, and Storage					
1980	8.0×10^2	4.0×10^3	\$ -	Negligible	Negligible
1985	2.3×10^3	1.1×10^4	12.4×10^8	"	"
1990	4.4	2.1	19.9	"	"
1995	8.3	3.8	25.4	"	"
2000	12.7	6.0	26.7	"	"

would be similar to those for nuclear power plants. About 10 percent of the 350 staff of the reprocessing plant were assumed to be engineers for the calculations. Although most of the workers will have to be quite skilled (extensive training programs will be required), the need for engineers is probably not as great as in nuclear power plants.

Although the fuel fabrication plants and the facilities for converting U_3O_8 to UF_6 are small in comparison with other components of the nuclear industry, an attempt was made to estimate the manpower and capital requirements based on the information in Table C-14, which was obtained via telephone conversations [Hauser - 74 and Shelley - 74].

The steel and concrete figures were estimated by multiplying the unit requirement for a particular type of plant by the number of plants of that type in the third year of construction in a particular year. (The percentage of plants of various types were estimated from AEC data [AEC - 74].) Then, the requirements for each type of plant were summed for that year.

An important aspect of the requirements that was not addressed in this study is the quantity of equipment necessary in these nuclear power plants and support facilities. These requirements include not only the reactor and reactor vessel, but also the components of the various systems in the plant (turbines, generators, generator buses, heat exchangers, pumps, cranes, condensers, tanks, monitoring and communication equipment, etc.). Some of these requirements have been discussed in the Atomic Industrial Forum Report [AIF - 73], which indicates that licensing and uranium supply are the two most apparent bottlenecks in their study.

An additional consideration in the nuclear industry that needs to be discussed is the quantity and fate of the radioactive wastes associated with the nuclear power plants.

Assuming that 1086 nuclear reactor power plants are operating in 2000 A.D., approximately 1.1×10^4 canisters containing about 8.1×10^5 cubic feet of solid high level waste will be produced in that year. The accumulated wastes in 200 A.D. from these reactors would fill about 8.0×10^4 cannisters that would require storage (assuming that about wastes equivalent to 3.0×10^4 will be in reprocessing plants).

The path requirements for FTFB and AFTF are shown in Tables C-16 and C-17.

TABLE C-16 AFTF - Path Requirements

	Manpower Engineers	Manpower Non-engineers	Capital	Steel (tons)	Concrete (yd^3)
Nuclear Reactor Power Plants					
1980	2.8×10^4	5.6×10^4	$ 11.8×10^9	2.8×10^4	3.0×10^5
1985	3.5	9.1	26.6	4.3×10^5	4.3×10^6
1990	3.4	8.1	22.2	4.5	4.6
1995	3.8	9.9	25.9	4.5	4.6
2000	3.7	9.3	22.8	4.9	5.0
Fuel Fabrication					
1980	-	-	-		
1985	400	2000	$ 120×10^6	Negligible	Negligible
1990	600	3000	60 x	"	"
1995	800	4000	60	"	"
2000	1000	6000	60	"	"
Enrichment					
1980	9.7×10^2	6.5×10^3	$ 1.65×10^9	4.8×10^4	2.0×10^5
1985	7.6×10^2	5.5	1.1	2.4	1.0
1990	1.0×10^3	7.3	2.2	6.0	2.5
1995	9.7×10^2	7.3	1.1	3.6	1.5
2000	8.9	9.0	2.2	4.8	2.0
Reprocessing					
1980	6.8×10^2	4.7×10^3	$ 270×10^6	6.0×10^4	6.0×10^3
1985	7.1	5.0	270	6.0	6.0
1990	7.2	5.0	270	6.0	6.0
1995	7.5	5.3	270	6.0	6.0
2000	7.9	5.6	270	6.0	6.0

TABLE C-17 FTFB - Path Requirements

	Manpower Engineers	Manpower Non-engineers	Capital	Steel (tons)	Concrete (yd^3)
Nuclear Reactor Power Plants					
1980	2.2×10^4	7.4×10^4	\$ 27.5×10^9	3.9×10^5	4.0×10^6
1985	2.1	7.8	21.8	5.3	5.5
1990	1.8	6.9	16.7	4.2	4.3
1995	1.5	5.4	11.9	3.4	3.5
2000	1.3	3.9	6.8	2.4	2.5
Enrichment					
1980	9.7×10^2	6.5×10^3	\$ 1.65×10^9	4.8×10^4	2.0×10^5
1985	7.6×10^2	5.5	1.1 x	2.4	1.0
1990	1.0×10^3	7.3	2.2	6.0	2.5
1995	9.7×10^2	7.3	1.1	3.6	1.5
2000	8.9	9.0	2.2	4.8	2.0
Reprocessing					
1980	6.8×10^2	4.7×10^3	\$ 270×10^6	6.0×10^4	6.0×10^3
1985	7.1	5.0	"	"	"
1990	7.2	5.0	"	"	"
1995	7.5	5.3	"	"	"
2000	7.9	5.6	"	"	"

Impacts

All impacts in this section are judgements by the design group and not a part of this scenario. Most of the impacts of the nuclear industry will be present in all three scenarios; however; the tremendous expansion projected by the NEE scenario would have much larger impacts than the other two. Therefore, the impacts are not separated into sections. Instead, a discussion of the various impacts is combined in one section. Some of these impacts have already been noted by many people and are under study in some cases; others are postulated as results of some event which may occur.

Economic

Some economic impact might result if at some point in the future, construction of nuclear power plants were halted for any one of a variety of reasons:

Fusion becomes a reality so that fission is no longer necessary.

The use of solar energy in peak shaving becomes wide-spread. In this event additional nuclear generating capacity might be curtailed.

The breeder does not fulfill the projected requirements, thereby leading to a U-235 shortage.

Moratoriums are declared on further construction.

Suppose fusion does become a reality before the turn of the century or soon thereafter. Some of the questions to consider in this event are: Where can fusion reactors be built? Will most of the available sites have been used for fission reactors? Could an old plant be dismantled with appropriate safety regulations so that a fusion reactor could be built in its place?

The use of solar or fusion power would probably have a minimal impact on society and industry because developmental reactors or plants would be built prior to implementation. Consequently, the public and industry would have time to adjust to these changes.

On the other hand, suppose a moratorium were declared on further power plant construction as the result of some kind of freak accident or sabotage! What would be the effects on society and on the economy of such an abrupt change? If the rate of growth were slow and orderly rather than unrestrained, these kinds of impacts might be more easily handled.

Another economic impact that might be considered is the exportation of nuclear energy products (reactors, enriched uranium, monitoring instruments, etc.) Apparently these products will form a sizable portion of U.S. exports in the future. Large purchases of nuclear products will obviously have a positive effect on our balance of payments. If a large portion of the U.S. industry were devoted to the overseas market, the magnitude of many of the requirements enumerated in this appendix would increase.

Another economic impact associated with nuclear power might be the abil-

ity of the industry to pay higher prices for scarce commodities such as steel and skilled labor. If higher prices resulted, then inflation would continue.

An additional economic consideration might be the effect of delayed construction times on capital investment. The increased cost is probably passed on to the consumer driving the cost of electricity higher and resulting in further inflation.

Another possibility to consider is, to what extent should the cost of nuclear waste disposal be included in the cost of electricity.

If the electric utilities can sell their energy for 2¢/KWH, by the year 1990 they will be taking in revenues at the rate of more than $100 billion/yr. Integrated over the 25 years from 1975 until the turn of the century, they will make several trillion dollars. Of course, this wealth will be spread widely through the financial institutions of the country.

Environmental

The effects of nuclear fission on the environment have been debated for several decades and many of the issues have still not been resolved. However, the fact that concern is expressed over the realease of radioactive materials to the environment via nuclear reactors must be addressed.

The release of alpha-emitting daughters of uranium (Rn and Ra) in the mining and milling processes is one such area of concern. Apparently radon gas in underground mines causes lung cancer in miners [Eisenbud-63]. Radium-226 (half-life of 1622 years), which is present in the tailings of uranium mills, is also a radiological hazard.

The production of plutonium at the rate of 1200 Kg/day by 2000 A.D. is of great concern to some people. Small quantities of plutonium may escape even though most of it is fissioned before leaving the reactors and the remainder is reclaimed via processing or encapsulated with the high level waste. Some critics claim that a few hundred atoms of ingested plutonium will cause bone and lung cancer, while others point to past human exposure at the Nevada weapons test site, Alamagordo, and Nagasaki and ask for experimental verification of this claim. The second area of concern in handling plutonium is the possibility of clandestine weapons manufacturing by nations (e.g. India) or smaller groups such as the Irish Revolutionary Army, the Palestine Guerrillas, or the Symbionese Liberation Army. Many people are worried about the possibility of homemade atomic bomb [Leventhal-74]. The nuclear industry must provide sufficient security to prevent this possibility from becoming a reality.

The highly radioactive fission products are another source of concern for many people. Most of the fission products have short half lives and decay to stability before the fuel leaves the reactor. However, some of the remaining radioactive isotopes, such as Kr-85 (half life, 10.6 yrs), Sr-90 (half life, 27 yrs), Tc-99 (half life, 210,000 yrs), I-129 (half life, 10.7 million yrs), Cs-137 (half life, 30 yrs), Pr-147 (half life, 2.6 yrs), and Sm-151 (half life, 290 yrs), are responsible for the concern voiced by these people.

Dissolving spent fuel elements in reprocessing plants results in the release of radioactive gases such as Kr-85, a heavy gas that tends to gravitate to the bottom of the atmosphere. Being quite soluble in cold water, some kryton-85 dissolves in the polar seas (after being carried there by wind currents) before it decays.

Strontium-90, the most dangerous of the fission products, is chemically analogous to calcium. If ingested, it has a long residence time in the bones. Strontium-90 is formed in about 6 percent of the fission events [Zysin-64].

Since cesium has chemical properties similar to those of potassium, cesium has a short biological half life, 140 days, [Eisenbud-64]; therefore, within a year the body can eliminate nearly all of the cesium obtained in a single exposure.

The half-lives of iodine-129 and technicium-99 are sufficiently long that their hazard is greatly attenuated if they pass through the body. However, iodine collects in the thyroid gland. Samarium-151 is a trace element, and promethium is not a naturally-ocurring element. Apparently, these elements are not used in the life processes. Consequently, external hazard associated with the gamma rays accompanying beta decay is probably greater than the internal hazard for all of these except iodine.

The transuranic elements in spent fuels are very toxic alpha-emitters. Some of the isotopes undergo spontaneous fission. Most have long half-lives -- for example 24,600 years for Pu-239. If these long-lived isotopes are not removed from the waste, they dominate the remaining activity after 500 years. Therefore, it appears that separating these isotopes chemically in order to eliminate the long-term (700 yrs+) toxicity of the waste is advantageous [Rose-73].

Tritium, another radiological problem, comes primarily from three sources:

> It is formed as a ternary fission product in about 0.01 percent of the fission events [Hyde-64].
>
> A neutron reaction with boron, a burnable poison used in some pressurized water reactors, also yields tritium [Foster-73].
>
> The absorption of a neutron by deuterium in the heavy water reactors also esults in tritium formation. In a 640 MWe CANDU design, tritium is formed at the rate of about 5×10^{18} atoms per second, resulting in an equilibrium concentration of 2.8×10^{27} atom (14 Kg) of tritium in 480 tonnes of D_2O. Although most of this tritium never escapes from the closed moderator containment, the 10Kg per day make-up rate indicates that a CANDU reactor will release 7×10^{22} atoms of tritium per day.

Tritium is the only radioactive atom produced in significant quantities by nuclear reactors that can be incorporated into DNA molecules. There is some speculation that tritium is sufficiently different from hydrogen (atomic mass 3 to 1) that changes in

molecular biology may occur even without decay. Since tritium is not preferentially absorbed, the ratio of tritium atoms to the normal hydrogen isotope may be significant. If sometime in the future we get a worldwide economy based mostly on nuclear energy, the ratio of man-made tritium atoms to hydrogen atoms would be about 1 : 4 x 10^{18}. Natural tritium formed by cosmic rays would be 1 : 1 x 10^{18}, so there would be four times as much natural tritium as man-made. [Jacobs - 68].

One question that still has not been satisfactorily answered is, what happens to a nuclear power plant once it ceases operation? What is the procedure for decommisioning an old reactor?

Another area that might be considered is the large number of people that will be working in the atomic industry. These people will be receiving up to 10 times the dose of radioactivity received by the average individual.

In the area of thermal pollution, both nuclear and fossil fuel power plants produce large quantities of waste heat due to their low efficiencies. Generating the 1300 GWe projected for the U.S. by 2000 A.D. would require the evaporation of 3.6 x 10^{16} cm^3 of water per year (a cube 2 miles on a side). This amount of water in the form of rain would yield 0.42 cm/yr if spread uniformly over the entire country. While this amount of rain may appear negligible when spread out uniformly, it may have some effect on local climatic conditions when power plants are sited in the same vicinity.

Of particular interest in the discussion of thermal pollution and local climatic effects is the Nuclear Power Park complex. This type of concept has been proposed as an answer to the questions raised about the security surrounding the handling (especially during transportation) of the radioactive wastes containing plutonium and the reprocessed plutonium itself. The Nuclear Power Park Concept envisions a complex of power plants, fuel fabrication, enrichment, and reprocessing facilities all inside the same fence in order to minimize transportation of the uranium fuel, the wastes, and the plutonium. The problem of thermal pollution would be compounded by siting increasing numbers of nuclear power plants on one site. Transporting the electricity produced to the users would require huge quantities of transmission lines (unless super-conducting transmission lines are perfected). Not only would obtaining the necessary right-of-way become an obstacle but also the noise pollution produced by large numbers of transmission facilities might become a problem. One other major consideration in the construction of Nuclear Power Park Complexes is the siting problem. How many suitable sites can be found? Will the public be willing to accept the risk, the waste heat pollution, the noise, etc. that would accompany this type of complex? The public might prefer single unit reactors.

Before leaving the discussion of the "dangers" associated with radioactivity, it should be noted that permissible doses of radioactivity are very conservative. For example, experiments indicate that the mutation rate in mammals increases less than 1 percent when the background radiation level is doubled [Asimov - 66]. This kind of result implies that 99 + percent of natural mutations are caused by factors other than radiation.

However, more effort is concentrated on reducing the 1 percent sector than the 99 percent sector.

A different kind of environmental problem is involved in the mining and milling operation. Should the land be returned to some reasonable form of contour? Should this be a part of the cost of the fuel?

Some of the social impacts of an expanding nuclear industry are discussed below.

The large influx of construction workers to a remote site must have considerable impact on the existing social structure, in addition to the economic and environmental impacts. Who is responsible for supplying water and sewer facilities for these workers? Do the schools become overcrowded? Is there sufficient housing? What kinds of living conditions will be allowed? Are shopping facilities adequate? If facilities are expanded, what happens when the construction force leaves? Are new zoning laws required?

Construction of Nuclear Power Park Complexes could lead to the location of industries in the vicinity (hopefully some industries can be persuaded to use the waste heat discharged from power plants). The location of industries could lead to the growth of cities around these complexes. In this case, serious consideration might be given to the location of these complexes.

The effect of the continuing nuclear energy debate between the large vested interest groups and the groups trying to prevent new construction of nuclear power plants is still unknown. Perhaps the public will grow weary of the debate and will allow easier siting and licensing procedures to be introduced.

The increasing needs for nuclear-trained technologists may require early career choices of young people and better education facilities in the future. In fact, lead times here are probably on the order of 15 years.

The magnitude of the numbers of craftsmen needed to build the projected power plants causes serious concern on the part of many people. The slow increase in the membership of building trade unions of the AFL-CIO, the major source of skilled craftsmen for the industrial sector causes additional concern. The data released by the AFL - CIO in October, 1973, indicates that even in the fastest growing union, electrical workers, the increase is less than 3 percent per year compounded annually. [INAE - 74]. Craftsmen in construction areas other than the industrial category, for example, manufacturing industries such as electrical manufacturing and pipe fabrication, are included in these figures. The workers in the "industrial" construction category constitute less than 10 percent of the total in the specified crafts. One area of serious concern in the craftsmen supply is the number of pipefitters, welders, and electricians needed. This may indeed be a serious impact unless plans

are made to train more people in these fields.

In addition to the problems of numbers and training of workers, the mobility of labor must be considered. Since the mobility of labor, particularly in the construction trades, has been lessening in recent years, incentives to persuade people to relocate will probably increase with resultant increases in cost.

The decline in building construction labor productivity has been the topic of many discussions on union work rules. Such trends need to be reversed if requirement for the future are to be met.

Another consideration is that maintaining competitive status in world markets and providing jobs for an expanding labor force requires energy and productive machines. A large share of the most talented people from the universities are needed by the energy industry if they are to continue to supply the industrial economu with its energy needs. [NAE - 74]. Unfortunately, current enrollment trends appear to be away from the discipline most needed in the energy industry.

C-1-2 FOSSIL-FUELED ELECTRICAL GENERATION

Present Situation

Generation of electricity in fossil-fueled plants is the backbone of the electric power industry. Despite the publicity attending nuclear power, 72.6 percent of the U.S. electrical generation capacity at the end of 1973 is in the form of fossil-fueled steam plants. In addition, 7.5 percent of total capacity is from gas turbine units and 1.1 percent from internal combustion engines turning electrical generators. Thus, fossil-fueled electrical generation plants presently comprise 81.2 percent of the total U.S. generation capacity. [EWSR-74]

Moreover, electrical generation with fossil-fueled steam plants is a mature technology. Figure C-9 shows the historical growth of the U.S. electric power industry by generation method. Based on an average plant life of 35 years [FPC-70], many fossil-fueled steam plants are in their middle years of useful life. Operational data are available to assist in the design of new plants. These data have contributed to the rapid application of gas turbine technology from the aircraft industry to power plants. To meet increased demand in recent years, the electric power industry has brought additional gas-turbine capacity on line within 2 to 4 years, in contrast to the 6 to 8 years needed for fossil-fueled steam plants and 10 years for nuclear plants.

The total capacity of 438.5 GW at the end of 1973 yielded 1579 x 10^9 KWh of electricity during 1973 including 1495 x 10^9 KWh with fossil fuels and 81 x 10^9 KWh from nuclear fuel. This translates into utilization of fossil-fuel plants on the average for 48 percent of their possible output if run continuously at capacity during an entire year. Nuclear plants in service produced at 44 percent of the possible output. However, many fossil-fueled plants are relegated to intermediate or peaking duty while present nuclear plants are designed exclusively for baseload duty. Thus, the maturity of fossil-fueled electrical generation technology is further documented.

Fossil-fueled electrical generation does not imply coal-fired plants. The electric power industry is required to meet the demand for electricity but is constrained by regulations on the burning of high sulfur coal and the lack of adequate methods for preventing sulfur emissions. The fuel mix for electricity generated in 1973 is shown in Table C-18. The amounts of oil and gas consumed includes fuel for plants originally designed to burn coal. Also, the coal consumed includes low-sulfur coal transported to plants near high sulfur coal deposits. The fact is that much oil and gas is used by the electric power industry.

The concern over supplies of environmentally acceptable fuels for electrical generation is reflected in the present growth plans of the electric power industry.

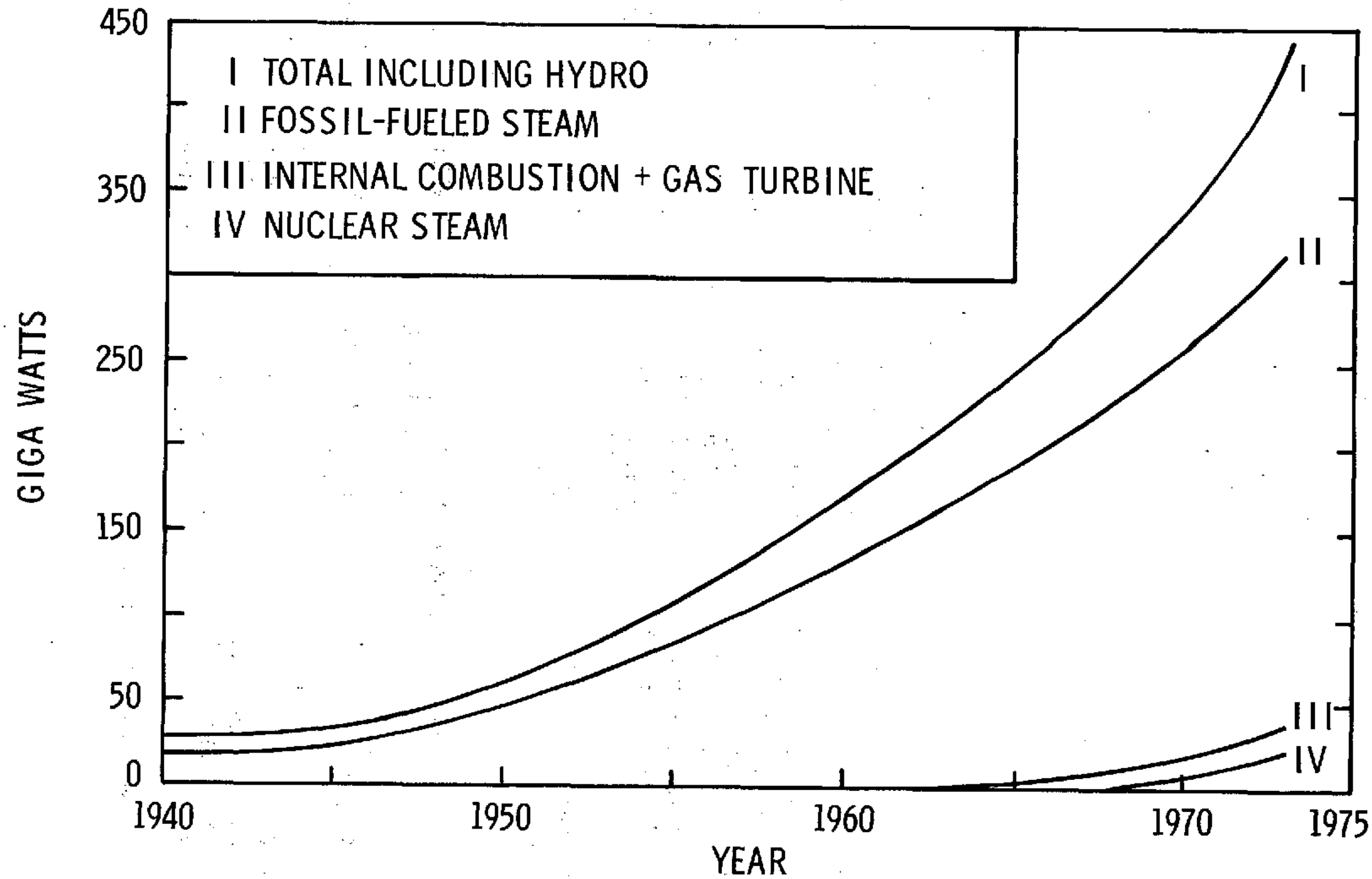


FIGURE C-9 U.S. ELECTRICAL GENERATING CAPACITY [FPC-70 and EWSR-74]

TABLE C-18 1973 FUEL MIX FOR ELECTRICAL GENERATION (EXCLUDING HYDRO)

Fuel	Billions of KWh	Percent	Consumption
Coal	843.6	53.4	386.6×10^6 TONS
Oil	314.7	19.9	565.5×10^6 BBL
Gas	337.5	21.4	3.75×10^{12} FT^3
Nuclear	81.3	5.2	NOT GIVEN
Geothermal, etc.	2.2	.1	---------------

Data from EWSR-74

TABLE C-19 PRESENT GROWTH PLANS FOR ELECTRIC POWER

Plant Type	End of 1973 MWe	%	After Completion of Present Plans MW	%
Fossil-fueled Steam	318357	72.7	482363	56.3
Gas Turbine	32877	7.5	59248	6.9
Internal Combustion	4908	1.1	5501	.7
Nuclear Steam	21070	4.8	220323	25.7
Conventional Hydro	53667	12.2	65541	7.6
Pumped Storage Hydro	7613	1.7	24420	2.8
	438492		857396	

Data from EWSR- 74

TABLE C-20 NUMBERS AND AVERAGE SIZE OF GENERATING PLANTS AT END OF 1973

Plant Type	Capacity (MW_e)	Plants	Ave. Size
Fossil-fueled Steam	318357	977	327
Gas Turbine	32877	457	72
Internal Combustion	4908	989	5
Nuclear Steam	21070	43	490
All Hydro	61280	1159	53

Data from EWSR-74 and AEC-74

Table C-19 compares the 1973 installed capacity by generation method to capacity after completion of projects now in various stages of firm planning or construction. The electric power industry is committed to nearly doubling its generation capacity and plans to accomplish this growth by more than a 50 percent increase in the installed capacity of fossil-fueled steam units and an 80 percent increase in gas turbine units. Considering the amount of fossil-fueled capacity already installed, these plans are very ambitious. They seem especially so in light of plans for nearly a 950 percent increase in nuclear steam capacity from the small capacity presently installed. However, it is evident that there will be a shift from the mature fossil technology mainly because of fuel supplies. Reliance is placed on nuclear fuels despite limited operational experience with nuclear units.

Although the electric power industry plans to grow by dramatic increases in nuclear and fossil-fueled capacity, the fossil-fueled plants presently installed are not easily replaced. To illustrate this point, Table C-20 breaks down the U. S. electrical generation capacity at the end of 1973 into numbers of plants and average plant size for each generation method. Note the small average size of fossil-fueled plants compared to nuclear plants. This feature is an outgrowth of the industry's past efforts to site plants near the load center they serve and the need to have small capacity units for intermediate and peaking duty. However, economy of operation favors large plants. Nuclear plants and new fossil-fueled steam plants are designed for baseload duty to take advantage of large plant economy. But the backbone of the present electrical power industry, the existing fossil-fueled plants, will be retired only when replacement is economically justified without a decrease in quality of service. Since there are 1065 separate electric utilities in the United States today and each has an exclusive service territory, such decisions will probably be based largely on the needs of an individual utility unless there is a dramatic restructuring of the industry.

Unit Requirements

In this section, data are presented on the funding, manpower and materials requirements for construction and operation of a fossil-fueled steam plant judged to be typicial of units to be added in the near future. The construction capital costs, operation costs and maintenance requirements per unit of electrical power generated favor large central station generating units. The present capability of the industry is units delivering 1300 MW each. Multiple unit plants of 5000 MW_e are foreseen by 1980 and the trend to larger units and plants is not predicted to level off before 1990. Peaking unit size is generally from five to ten percent of total system capacity so that peaking units as large as 1000 MW_e are feasible. [FPC-70]

Therefore, a typical fossil-fueled unit to be used as a building block for additional capacity is taken to be a 1000 MW_e unit. It is presumed this unit will be part of a multiple unit plan. The Tennessee Valley Authority provided data on the 1150 MW_e unit 3 of their Paradise plant and the two 1300 MW_e units comprising their Cumberland plant. All three units are coal fired. Table C-21 presents a summary of these data normalized to a 1000 MW_e coal-fired unit. These data do not reflect requirements for lessening environmental impact such as water quality standards or installation and operation of sulfur dioxide removal meeting

TABLE C-21 REQUIREMENTS FOR A COAL-FIRED STEAM UNIT DELIVERING 1000 MW OF ELECTRICAL POWER (8840 BTU/KWh HEAT RATE)

Construction Materials (In addition to Plant Components)

Land: (approximate) 500 Acres/GW
Steel: Reinforcing, 3400 T/GW; Structural, 13300 T/GW
Concrete: 54,000 YD^3/GW
Funds: (approximate) \$300 x 10^6/GW (1974)

Construction Manpower

Overall: Design: 350 Man-Yrs/GW; Construction: Non-Manual - 330 Man-Yrs/GW; Manual 6.5×10^6 Man-Hrs/GW

Skills Required:	Man-Hr/GW
Steamfitters	10.0×10^5
Electricians	9.6×10^5
Boilermakers	9.2×10^5
Laborers	8.8×10^5
Steelworkers	6.5×10^5
Operating Engrs.	6.2×10^5
Carpenters	6.2×10^5
Painters, Masons, Machinists, etc.	7.7×10^5

Operating and Maintenance

Fuel: 2.75×10^6 T/GW-YR (80% Duty and Midwest Coal).
Water: Direct cooling, 3×10^5 GAL/MIN-GW; Evaporative Cooling Tower, 2×10^4 GAL/MIN-GW for Evaporation & Blowdown
Capital: (approximate) \$.50 to \$1.00/10^6 BTU for Fuel
Manpower: 120 Employees/GW

equipment. Such matters will be addressed in the section on impacts. The data for a large oil-fired or gas-fired steam unit can be taken as approximately the same except, of course, for fuel. National average heating values are, for coal, 11640 BTU/lb; for residual fuel oil, 6.287 x 10^6 BTU/bbl; and, for natural gas, 1038 BTU/SCF[CEQ - 73]. The Midwest coal used in Table C-23 has a heating value of 11260 BTU/lb. Adjusting the data in Table C-23 for the appropriate average fuels yields the following fuel rates: 2.66 x 10^6 T/GW-yr (11640 BTU/lb-coal); 9.85 x 10^6 bbl/GW-yr (6.287 x 10^6 BTU/bbl-oil); and 59.7 x 10^9 SCF/GW-yr (1038 BTU/SCF-gas).

According to present development schedules, another type of coal-fired plant will be available as a building block for fossil-fueled electrical generation after 1980. This is the combined gas and steam (COGAS) cycle plant. Herein, coal is first converted to a low heating value (approximately 150 BTU/SCF) gas by a coal gasification process. After removal of sulfurous gases and particulate matter, the power gas is burned in air and fed to a gas turbine turning an electrical generator. The gas turbine exhaust is routed through a boiler to raise steam for a steam turbine turning another electrical generator.

The COGAS cycle promises higher overall plant efficiencies than are foreseen with steam cycles alone. Moreover, the removal of sulfur compounds is achievable with known technology. Hence, the COGAS cycle offers an attractive means for utilizing coal for electrical generation. The basic requirements for a 1000 MW_e COGAS plant are presented in Table C-22 from data supplied by the Foster Wheeler Corporation [McAllister - 74]. It is assumed that alternate means for using coal at increased efficiency, namely, magneto-hydrodynamic and liquid metal topping cycles, will not be significant before the year 2000.

Path Requirements

The requirements for fossil fueled electrical generation are dependent upon the amount and types of fuel available. The fossil fuel mixes used for electrical generation for the energy futures analyzed herein are given in TABLE C-23 However, the average life of 35 years for fossil fueled units has two consequences. In order to maintain capacity, units must be continually replaced because of retirements. On the other hand, many oil and gas-fired units will continue to be used until retirement allows replacement. Unless coal handling and combustion facilities are retrofitted to oil and gas units, the present trend toward clean fueled units will be felt until the year 2000 in all scenarios and may require use of synthetic fuels from coal for electrical generation.

Gas turbine units appear identically in all scenarios. The combination of present plans for such units and an extrapolated leveling off of capacity yields the numbers used. Internal combustion units are taken at their present number in all scenarios. By subtracting gas turbine consumption from the total gas available for electrical generation, the fuel available for gas fired steam units is obtained. Similarly, oil for steam units is the

TABLE C-22 REQUIREMENTS FOR A COGAS UNIT
DELIVERING 1000 MW OF ELECTRICAL POWER
(8650 BTU/KWh HEAT RATE)

Construction Materials (In addition to Plant Components)

Land: (approximate) 500 Acres/GW
Steel: Reinforcing, 3500 T/GW; Structural, 20,000 T/GW
Concrete: (approximate) 80,000 yd^3/GW
Funds: \$375 x 10^6/GW (1974)

Construction Manpower

Overall: Design: 250 Man-Yrs/GW Construction: Non-manual - 250 Man-Yrs/GW;
Manual - 5.5 x 10^6 Man-Hrs/GW

Skills Required:	Man-Hr/Gw
Pipefitters and Welders	19.0 x 10^5
Electricians	9.0 x 10^5
Laborers	11.0 x 10^5
Steelworkers	8.0 x 10^5
Operating Engineers	3.0 x 10^5
Others	5.0 x 10^5

Operating and Maintenance

Fuel: 2.69 x 10^6 T/GW-Yr (80% Duty and Midwest Coal)
Water: (approximate) 3 x 10^4 GAL/MIN - GW Total Use (Cooling + Process)
Funds: (approximate) \$.50 to \$1.00/10^6 BTU for Fuel
Manpower: 110 employees/GW

TABLE C-23

FOSSIL FUELS FOR ELECTRICAL GENERATION (Quadrillion BTU)

	1975	1980	1985	1990	1995	2000
Coal, Direct (Incl. COGAS):						
NEE[a]	9.	14.	20.	24.	28.3	29.6
FTFB[b]	9.	12.	14.5	16.5	17.	17.
AFTF[c]	9.	15.	18.	18.5	18.	17.
Oil (Residual Fuel Oil):						
NEE[a]	3.	2.5	2.	1.8	1.6	1.5
FTFB[b]	3.	3.3	3.5	3.7	3.8	4.
AFTF[c]	3.	3.7	4.	4.	4.	4.
Gas (Incl. SNG):						
NEE[a]	4.	6.	8.	8.	8.	8.
FTFB[b]	4.	3.8	3.6	3.4	3.2	3.
AFTF[c]	4.	3.	2.5	2.	2.	2.

[a]Fossil fuels for electrical generation and fuel mix specified by scenario authors [ROSS-73-1].

[b]Fossil fuels for electrical generation obtained in telephone conversation with Ford Energy Policy Project staff. Fuel mix uses same relative amounts as reported for NEE base case [Ross-73].

[c]Approximately same fuel mix as FTFB in year 2000 with attempt to level off installation of new generation capacity after 1990.

amount left after filling the needs of the internal combustion units. The product of capacity, plant factor (fraction of possible output during a year) and heat rate (fuel use for a unit of output electricity) yields annual fuel use. Assuming reasonable factors and heat rates, the capacities of coal, gas and oil-fired steam units are obtained for each future. The coal-fired capacity is divided between steam units and COGAS units. The number of the latter is determined by postulating a reasonable growth of installed COGAS capacity starting in 1980.

The annual capacity by type of fossil-fueled unit results from the above procedure. By taking the difference between the capacity for a given year and the capacity for the preceding year, numbers are obtained for the annual change by type of unit. After including effects of retirement, the annual additions to capacity are available. These values translate into construction requirements and total capacity translates into annual operating requirements by using the building block data in TABLES C-21 and C-22.

Results of determining the path requirements for fossil fueled electrical generation in selected energy futures are shown in Table C-24. In all cases, the water required assumes use of evaporative cooling towers. fuel requirements use the average heating values of coal, oil, and gas [CEQ-73]. Construction requirements are averaged over the lead times for the respective units. These lead times are taken as 8 years for coal-fired units, 6 years for oil and gas-fired steam units and 4 years for gas turbine units. All three energy futures reveal the assumption that installation of fossil fueled electrical generation capacity will not continue at its present rate of growth toward the year 2000. Moreover, the total coal use in the year 2000 will significantly exceed present use in all cases. However, oil and gas for electrical generation show no general trend.

Further insight into fossil-fueled electrical generation is offered by Table C-25. Starting from a common 1975 picture in which 370 GW capacity is used at a 46 percent plant factor and an average heat rate of 10670 BTU/KWh, the three energy futures go to different levels by the year 2000. The Nuclear Electric Economy (NEE) is the most ambitious, monotonicall increasing capacity by 131 percent, improving the heat rate by 12.5 percent and increasing utilization by 22 percent from 1975 values. The Ford Technical Fix (FTFB and AFTF) futures seek less remarkable improvements. The base case (FTFB) steadily adds capacity, improves heat rate and increases plant factor at a less accelerated pace than the NEE. The alternate case (AFTF) at 1985 surpasses the improvement in heat rate and plant factor sought by the NEE at 1985. All paths seek these improvements manly by replacing steam cycle units with COGAS units. The AFTF has the feature of slightly decreased capacity at 2000 from the 1985 value. This is a result of the attempt to level off installation of new fossil fueled limits after 1990. The retirement of units installed in the mid-1960's then shows up as decreased total capacity.

TABLE C-24

FOSSIL FUELED ELECTRICAL GENERATION REQUIREMENTS FOR SELECTED ENERGY FUTURES

	Annual: Coal ($T \times 10^6$)	Oil ($BBL \times 10^6$)	Gas ($FT^3 \times 10^9$)	Water ($GAL \times 10^{12}$)	Non-engineers	Engineers
1980						
NEE	990	680	11400	3980	181,700	18,700
FTFB	724	896	9250	3270	99,700	10,200
AFTF	827	1015	8240	3480	110,500	11,200
1985						
NEE	1317	571	13790	4970	163,200	17,100
FTFB	817	955	9610	3560	100,300	10,300
AFTF	1003	1123	7940	3930	100,700	10,500
1990						
NEE	1548	502	14210	5520	141,800	15,100
FTFB	870	1034	9490	3730	102,500	10,600
AFTF	1013	1123	7940	3960	89,200	9,400
1995						
NEE	1657	448	13850	5700	129,500	13,900
FTFB	896	1093	9490	3830	96,400	10,000
AFTF	976	1123	7880	3860	76,800	8,200
2000						
NEE	1700	409	13130	5700	125,200	13,500
FTFB	912	1133	9490	3880	82,700	8,800
AFTF	920	1123	7640	3760	60,500	6,700

TABLE C-24 (cont.)

5 Year:	1 GW Steam Units	1 GW Gas Turbine Units	Construction Funds (1972\$x10 ^{9})	Concrete (YD^{3}x10 ^{6})	Structural Steel (T x 10 ^{6})
1976-1980					
NEE	202	23	42.4	11.0	5.4
FTFB	86	18	18.0	4.6	2.3
AFTF	118	19	22.1	5.7	2.8
1981-1985					
NEE	118	57	31.8	8.2	4.0
FTFB	44	24	14.8	3.8	1.9
AFTF	56	35	14.8	3.8	1.9
1986-1990					
NEE	63	62	21.1	5.5	2.7
FTFB	44	25	14.6	3.8	1.9
AFTF	28	30	10.3	2.6	1.3
1991-1995					
NEE	38	37	13.7	3.5	1.7
FTFB	45	22	13.2	3.4	1.7
AFTF	21	18	6.8	1.7	0.9
1996-2000					
NEE	28	30	11.1	2.9	1.4
FTFB	36	18	8.9	2.3	1.1
AFTF	26	3	2.5	0.6	0.3

TABLE C-25

TYPICAL FOSSIL-FUELED ELECTRICAL GENERATION MIX

All:

1975	Capacity (GW_e)	Plant Factor	Heat Rate (BTU/KWh)	Fuel Use ($BTUx10^{-15}$)	Generation ($KWhx10^{-9}$)
IC	5	.1	11300	.1	4.4
GT	39	.1	11500	.4	34.2
FS:C	208	.46	10700	9.0	841.1
CG	--	-	--	-	--
O	64	.50	10500	2.95	281.0
G	54	.73	10500	3.61	343.8
Total	370	.46	10670	16.06	1504.5

NEE

1985	Capacity (GW_e)	Plant Factor	Heat Rate (BTU/KWh)	Fuel Use ($BTUx10^{-15}$)	Generation ($KWhx10^{-9}$)
IC	5	.08	11300	.04	3.5
GT	66	.08	11500	.53	46.3
FS:C	400	.44	10130	15.57	1536.9
CG	90	.66	8650	4.43	512.5
O	44	.48	10500	1.96	186.7
G	124	.65	10500	7.47	711.4
Total	729	.47	10010	30.00	2997.3
2000					
IC	5	.08	11300	.04	3.5
GT	73	.08	11500	.59	51.2
FS:C	292	.45	9700	11.04	1138.6
CG	350	.70	8650	18.56	2146.2
O	30	.53	10500	1.46	139.1
G	106	.76	10500	7.41	705.9
Total	856	.56	9340	39.10	4184.5

[a] IC=internal combustion; GT=gas turbine; FS=fossil steam; C=coal-fired; CG=combined gas and steam; o=oil-fired; G=gas fired.

TABLE C-25 (cont.)

FTFB:

	Capacity (GW_e)	Plant Factor	Heat Rate (BTU/KWh)	Fuel Use ($BTU x 10^{-15}$)	Generation ($KWh x 10^{-9}$)
1985					
IC	5	.08	11300	.04	3.5
GT	66	.08	11500	.53	46.3
FS:C	274	.54	10130	13.12	1295.3
CG	28	.65	8650	1.38	159.4
O	76	.50	10500	3.46	329.6
G	63	.53	10500	3.07	292.2
Total	512	.47	10160	21.60	2126.3
2000					
IC	5	.08	11300	.04	3.5
GT	73	.08	11500	.59	51.2
FS:C	192	.55	9700	9.04	932.3
CG	150	.70	8650	7.96	919.8
O	91	.47	10500	3.96	377.2
G	54	.49	10500	2.41	229.7
Total	565	.51	9550	24.00	2513.7

AFTF:

	Capacity (GW_e)	Plant Factor	Heat Rate (BTU/KWh)	Fuel Use ($BTU x 10^{-15}$)	Generation ($KWh x 10^{-9}$)
1985					
IC	5	.08	11300	.04	3.5
GT	66	.08	11500	.53	46.3
FS:C	318	.54	10130	15.34	1514.3
CG	54	.65	8650	2.66	307.5
O	90	.48	10500	3.96	377.2
G	40	.53	10500	1.97	187.4
Total	573	.49	10060	24.50	2436.2
2000					
IC	5	.08	11300	.04	3.5
GT	73	.08	11500	.59	51.2
FS:C	195	.55	9700	9.04	932.3
CG	150	.70	8650	7.96	919.8
O	90	.48	10500	3.96	377.2
G	28	.55	10500	1.41	134.4
Total	541	.51	9510	23.00	2418.4

Impact Analysis

The electric power industry grew during times of clean and abundant energy fuels to become a necessary contributor to the American way of life. Future growth, at least that which is assured by firm plans and construction, is more difficult in that the impact of each additional plant must be documented in relation to emerging standards. As one looks further ahead, however, it seems inevitable that serious conflicts will emerge between what is possible for the electric power industry and what is acceptable to their customers. To prepare for this situation, this section presents the annual impact of fossil-fueled electric generation units in terms of amounts of solid, liquid and gaseous wastes discharged and amount of land disturbed. Furthermore, the same quantities are given assuming application of pollution control devices now available or under development. No judgment about the future acceptability of these control measures is intended.

The basic unit for which data are given is a coal, residual fuel oil or natural gas fired generating unit delivering 1000 MW of electric power with an annual average duty of 80 percent. Such units were proposed as the building block units in the section on unit requirements. For coal, the results are shown in TABLE C-26 The air emissions from conversion are comprised mainly of particulates and sulfur oxide. The environmental control systems are presumed to remove 85 percent of SO_x and 99 percent of the particulates. Technology for SO_x removal is not available to achieve this level of removal at 80 percent duty. The results for oil are in TABLE C-27. With oil, SO_x and NO_x are the dominant emissions to air during conversion. Reduction in SO_x emissions and thereby the reduction in total emissions is achieved by specifying low-sulfur oil as the fuel. The results for natural gas are shown in TABLE C-28 Only NO_x emissions are significant, appearing in processing, transport and conversion from the combustion of natural gas with air. No controls except cooling towers are imposed.

The unique impact of fossil-fueled electrical generation is the production of sulfur oxides from coal and oil-fired steam units. When (or maybe even if) stack gas scrubbers for removal of SO_x are available, a difficult balance between economic and environmental factors will be required to bring about installation of scrubbers on existing units. The paths presented for all cases introduce COGAS units for which sulfur removal is part of the design. However, increased installation of COGAS capacity is not a viable alternative without forcing early retirement of other types of units or demanding COGAS capacity before the technology is available. The remaining alternative is to operate coal and oil-fired steam units without scrubbers at decreased plant factors when atmospheric conditions will tolerate the SO_x emissions. Because of the amount of electricity generated by these units, the ability of electric utilities to meet demand would be compromised.

Other impacts of fossil-fueled electrical generation relate to the supply of fuel and water for operation and materials and labor for construction. In general, the magnitude of these impacts cannot be judged alone. Further general discussion is deferred to the chapters on the overall impact of the separate energy futures. The rapid acceleration

TABLE C-26

ANNUAL IMPACTS OF A 1000 MW_e, 80% DUTY STEAM ELECTRIC UNIT BURNING COAL

(11639 BTU/lb, 2.6% by weight sulfur content coal; 8840 BTU/kw-hr heat rate)

	Mining		IMPACTS* DUE TO				Total	
	Deep	Surface	Processing	Transport	Conversion	Transmission	Deep	Surface
Land Use (Acres)	9550	14670 (978)	169 (89)	2317	729 (985)	17188 (30129)	29953	35073 (21557)
Water Used or Polluted (Tons)	2787 (0)	37510 (2934)	4035 (237)	--	851 (58)	--	7673 (295)	42396 (3229)
Emissions to Air (Tons)	NA	NA	4937 (62)	27510	368842 (47307)	--	401289 (74879)	401289 (74879)
Solid Waste (Tons)	101726 (106130)	2892366 (2892710)	475525 (484197)	--	53198 (1040917)	--	630449 (1631244)	3421089 (4417824)

*Numbers in parentheses apply if impact differs after application of environmental controls

All data from [CEQ-73]: adjusted to present heat rate and duty

TABLE C-27

ANNUAL IMPACTS OF A 1000 MW_e, 80% DUTY STEAM ELECTRIC UNIT BURNING OIL

(6.287×10^6 BTU/bbl, 1.5% by weight sulfur content oil; 8840 BTU/kw-hr heat rate)

	IMPACTS* DUE TO										
	Extraction		Refining	Transport			Conversion	Transmission	Totals		
	On	Off		On	Off	Import			On	Off	Import
Land Use (acres)	1646	172	80	1734	176	10	262 (272)	17188	20910 (20920)	17878 (17888)	17460 (17470)
Water Used or Polluted (Tons)	116	107	4850 (3208)	456	552	1792 (545)	851 (58)	--	6273 (3838)	6360 (3925)	2643 (603)
Emissions To Air (Tons)	--	--	91655 (3362)	1578	1578	1389	72593 (40173)	--	165826 (45113)	165826 (45113)	74171 (41562)
Solid Wastes (Tons)	--	--	-- (223)	--	--	--	--	--	-- (223)	-- (223)	-- (0)

*Numbers in parantheses apply if impact differs after application of environmental controls

All data from [CEQ-73]: adjusted to present heat rate and duty

TABLE C-28

ANNUAL IMPACTS OF A 1000 MW_e, 80% DUTY STEAM ELECTRIC UNIT BURNING NATURAL GAS

(1038 BTU/SCF gas; 8840 BTU/kw-hr heat rate)

	Extraction	Processing	Transport	Conversion	Transmission	Total
Land Use (Acres)	336	4	3337	157 (168)	17188	21022 (21033)
Water Used or Polluted (Tons)	--	--	--	851 (58)	--	851 (58)
Emissions To Air (Tons)	--	4431	7293	13476	--	25200
Solid Waste (Tons)	--	--	--	--	--	--

*Numbers in parantheses apply if impact differs after application of environmental controls

All data from [CEQ-73]: adjusted to present heat rate and duty

of the NEE path and the cutback in the AFTF will cause shifts of materials and labors among industries.

COGAS units are relied upon for their decreased SO_x emissions. However, they require many large compressors for the gasification and combustion components. Some shift from steam turbine manufacturing to building large compressor-gas turbine units is required. Moreover, COGAS plants will be a combination of chemical processing and power generation systems. The electric utilities need to hire engineers and laborers skilled in the design, construction and operation of chemical process equipment in addition to traditional power equipment expertise. The ability of the electric power industry to compete with the chemical and petroleum industries for these skills is not proven.

C-1-3. SOLAR GENERATION

Solar energy is, strictly speaking, the only inexhaustable energy source. Though none of the senarios analyzed in this report contain electrical power generated by solar energy, some background is included for the reader who may wish to apply the analysis method to other senarios which do include solar generation. In this section thermal electric conversion and direct photovoltaic conversion are considered because they seem to be the most promising methods for large scale power generation.

Thermal/Electric Conversion

A number of methods for obtaining thermal energy from solar radiation have been proposed, including parabolic troughs, fresnel lenses, parabolic dishes and central receivers using a field of heliostats. There are a number of ways to use solar generated thermal energy directly but of interest here is the conversion of this thermal energy into electrical energy. Any of the above methods of solar-thermal conversion can be used to create steam and drive a turbine/generator pair to generate electrical power. These methods differ in overall conversion efficiency which is primarily limited by the achievable coolant operating temperature.

Present Situation

From a land efficiency standpoint the parabolic dish is the best collector, but large units would be too cumbersome; control would be difficult, high winds would create structural design problems and dish surface maintenance would be difficult. Thus the parabolic dish is not a serious competitor. Considering physical limitations and overall solar to electrical conversion efficiency, two schemes look more promising than others.

The first is the central receiver concept [Williams-74], in which an array of individually controlled flat mirrors (heliostats) focuses the sun's rays directly onto a central reflector mounted atop a tower. The central reflector in turn focuses the energy onto a ground level converter which heats a coolant (probably molten metal or gas). The coolant passes through a heat exchanger creating steam to drive a turbine. An alternate scheme places the converter at the top of the tower, eliminating the need for the top reflector but requiring the molten coolant to flow the full height of the tower. TABLE C-29 provides insight into the field size, number of mirrors and tower heights required for peak electrical outputs ranging from 10 to 352 MW located in the southwestern U.S. For example a 10 MW plant would require a 0.4 km diameter field, a 100 meter tower and 800 mirrors each 9 meters square.

TABLE C-29 CENTRAL RECEIVER SOLAR POWER PLANT REQUIREMENTS [SPENCER-74]

100	150	200	300	450	600	Tower Height (meters)
0.4	0.6	0.8	1.2	1.8	2.4	Field Diameter (km)
33	73	132	293	660	1172	Equinox Power (MWth)
10	22	40	88	200	352	X 30% → (MW_e)

Mirror Size (Meters)

TOO SMALL

						Number of Mirrors
.67	1.0	1.3	2.	3.	4.	144,000
1.0	1.5	2.	3.	4.5	6.	64,000
1.3	2.	2.7	4.	6.	8.	36,000
2.	3.	4.	6.	9.	12.	16,000
3.	4.5	6.	9.	13.5	18.	7,100
4.	6.	8.	12.	18.	24.	4,000
6.	9.	12.	18.	27.	36.	1,800
9.	13.5	18.	27.	40.	54.	800

TOO LARGE

TABLE C-30 summarizes the power generation potential of central receiver type solar farms. These figures assume that 40 percent of the land area is actually covered by heliostats and that thermal/electrical conversion efficiency is just above 30 percent, for an overall solar/electrical efficiency of 12.5%. The average solar flux [Calvin-74] in the lower 48 United States is 200 w/m^2 averaged over day and night, summer and winter. Over this central portion, the sun shines about 65 percent of the possible time, indicating cloud cover 35 percent of the time. One square mile central receiver solar farms erected in this portion may be expected to generate 70 MW averaged over days and nights, summer and winter. This central region runs through San Francisco, Salt Lake City, Denver, Little Rock, Atlanta and Norfolk. In the highest average solar flux regions (China Lake, Las Vegas, Phoenix, Albuquerque and El Paso) similar solar farms would generate a yearly average of 91 MW. In the lowest solar flux regions (Seattle, Montpelier, Vt.) average yearly output would be 49 MW. Peak power output, summer at noon, would be about 210 MW for one square mile plants located in high flux regions. Peak values for plants in other areas would be slightly less than this since these areas lie further north.

TABLE C-30. CENTRAL RECEIVER SOLAR PLANT GENERATION POTENTIAL

Average Solar Flux, Watts/meter^2		Avg. Pct. of poss. Sunshine	Avg. Power Output MW/mi^2
260	(highest)	85	91
200	(average)	65	70
140	(lowest)	45	49

The second most promising scheme for solar/thermal power generation is proposed by Russell [Russell - 73, 74], and uses a fixed-mirror concentrator. A stepped surface cylindrical mirror produces a sharply focused line image regardless of the incident sun direction. The surface of this nonparabolic mirror would be formed by pressing metal foil into preformed asphalt or soil cement. As the sun moves, the line image moves along a circular path. A heat pipe containing air for the coolant is continuously positioned to remain along the focus line, but since the path of the line is circular, control is particularly easy as depicted in Figure C-10. A pebble bed provides heat storage for overnight or at least extended operation. The overall efficiency of Russell's scheme is about the same as for the central receiver, but the cost might be considerably less.

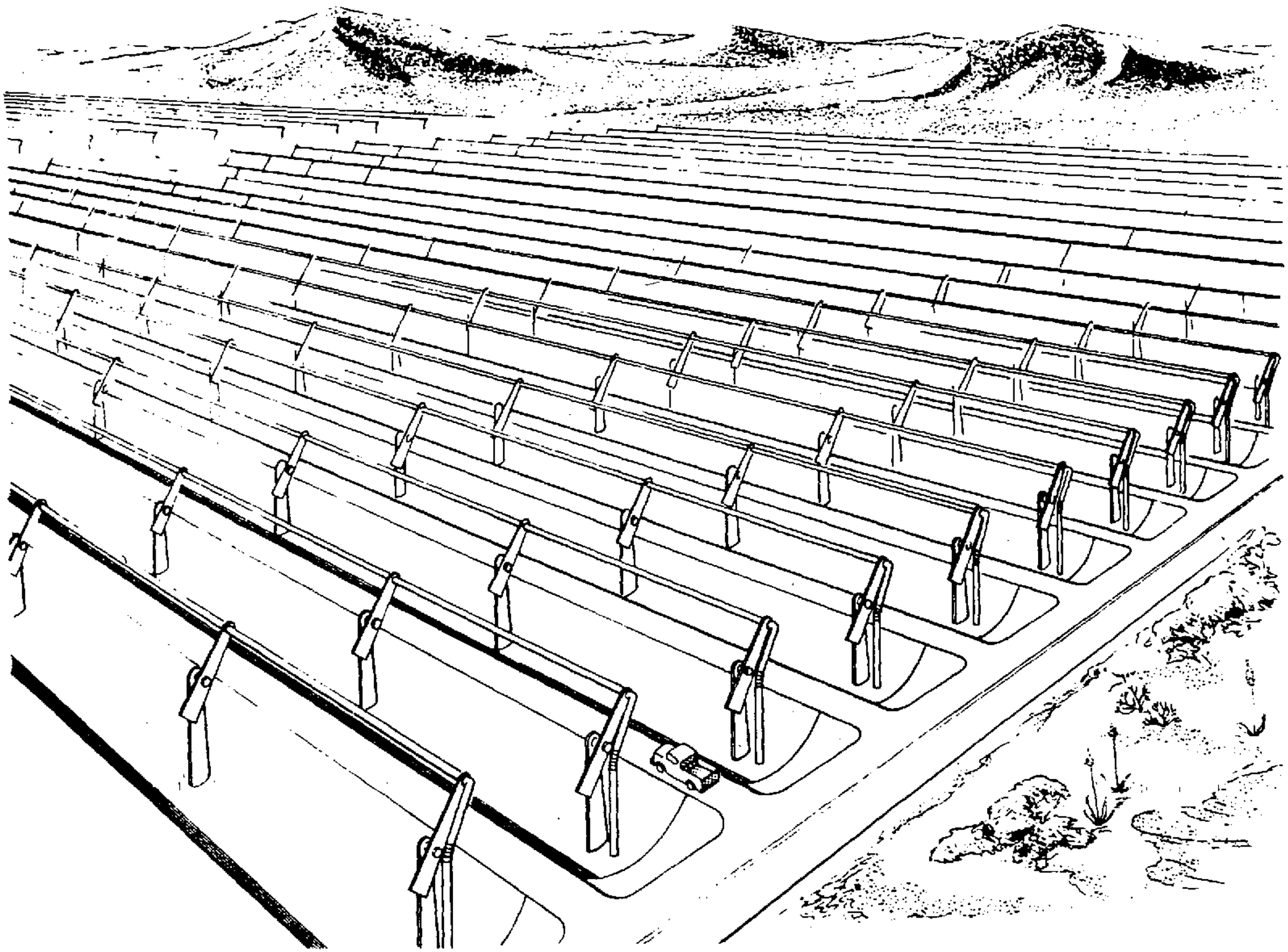


FIGURE C-10 FIXED MIRROR SOLAR FARM [Russell-73]

There are some interesting hybrid system possibilities which involve solar energy. One, a solar/coal combination, is currently under study by Sheldahl Corporation and Foster-Wheeler Corporation [Zoschak-74]. A version of the central receiver collector system comprises the solar portion of the plant. The energy collected would heat water or steam for use in a steam turbine cycle. Combining the solar energy collection system with afossil-fueled power plant would enable such an unit to function in a base load capacity. During cloudy days and at night, steam would be produced entirely by burning fuel in conventional boilers but on sunny days, solar heat would generate a large fraction of the thermal input.

Unit Requirements. No attempt has been made to specify requirements for a solar/thermal plant because none were required for the analyses performed in this report. However, a 10 MW_e central receiver pilot plant located in southern California and funded by NSF gives some indication of cost. The plant is to be completed by 1979 and is estimated to cost $90-100 million. This figure is equivalent to about $10,000 per kilowatt, 20 times the capital cost of current nuclear power plants. Naturally solar plant costs will drop sharply with experience. The key materials used in the central receiver plant would be steel and glass; and for the fixed-mirror plant steel and asphalt (or concrete). Russell has done an approximate cost analysis for the fixed-mirrorcase and indicates that this method might be immediately cost competitive with conventional power plants. Land requirements for either type of system can be estimated at about five square miles per GW_e or 3 acres per MW_e.

Photovoltaic Conversion

Conceptually, solar cells represent the best method of generating elctrical power because the conversion from solar power is direct. At present, however, solar cells are not competitive with other types of conversion because of high cost and low efficiency.

Present situation. The types of solar cells seriously being considered for power generation are single crystal silicon, polycrystalline silicon, cadmium sulfide and gallium arsenide [NSF/ RANN - 73]. Mainly due to the recently developed EFG method of growing large, continuous silicon crystals, single crystal silicon is the most promising type. Polycrystalline silicon cells, though easier to manufacture, have low (about 5%) conversion efficiencies. Cadmium sulfide is an interesting alternative. Though less efficient than silicon it is much less expensive. However, CdS deteriorates quite rapidly, and wide scale use would quickly deplete the U.S. cadmium resource. Gallium arsenide cells presently give the highest efficiency but are also limited by a materials shortage.

Currently at least two companies [Heliotek - 74, Solarex - 74] are marketing complete photovoltaic power systems for $20 per watt. Solarex markets cells alone for about $10 per watt in quantity. These figures

are considerably lower than last year's typical figure of $50 per watt and is an encouraging indication of the potential for future price reduction. Solar technology is reasonably advanced but silicon cell efficiency should be pushed closer to the theoretical limit of 22% and production costs need to be significantly reduced (to about $0.50 per watt) in order for large scale photovoltaic power generation to be economically competitive with conventional generation methods.

Electrical ouput from solar cells is in DC (direct current) form. Some electrical and electronic equipment and lighting can operate directly from DC and the coast guard, the forest service and others are presently using photovoltaic systems to power remote equipment. A number of spacecraft have been and are now operating from photovoltaic power. However, large scale power generation would necessitate inversion to AC in order to be compatible with existing grids. DC/AC inversion is perhaps 95% efficient using modern solid-state switching devices.

Unit Requirements. Unit requirements for a large photovoltaic electrical power plant are difficult to estimate so early in the industry's expansion. A variety of conventional building materials would naturally be required but the most important materials would be silicon for the cells and perhaps plastic and aluminum for cell containers and array supports. Silicon is one of the most abundant elements on earth and would not limit total production. Manpower requirements will likely be modest. Operating and maintenance requirements, for example, will probably be comparable to those for a hydroelectric plant.

Capital costs are speculative but the following milestones projected in a recent national photovoltaic workshop [NSF/RANN - 73] give some indication of future solar array costs.

1977: attainment of $5/watt (peak) technology

1979: attainment of $.50/watt (peak) technology feasibility

1981: completion of a pilot line to manufacture $0.50/watt (peak) solar arrays

1986: completion of a pilot line to manufacture $0.30/watt (peak) solar arrays

If these milestones are attained the increase in photovoltaic power generation would be as shown in TABLE C-31 and C-32. Thus we may expect photovoltaic systems of 10 to 100 MW capacity to actually be on line by 1990, and a total of 100 GW by the year 2000.

Expansion Requirements. The growth projected above requires several key accomplishments. The silicon refinement industry must be expanded

TABLE C-31 . ECONOMICS OF PHOTOVOLTAICS IMPLEMENTATION [NSF/RANN - 73]

Type/Time	Average* power, KW_e	Area, ft^2	Array, \$/watt (peak)	System $\$X10^3$	Operating $\$/10^3/yr$	Life, yr	Power cost, ¢/KWh	Life, yr	Power cost, ¢/KWh
Residence/1985	1	420	\$0.50	3	0	20	7	30	5
Central station/1990	10,000	$4.2x10^6$	0.10	7000	100	20	1.8	30	1.2
Residence/1990	1	420	0.10	1	0	20	1.6	30	1.0

*Average output power = Integrated peak insolation X (duty factor) X (system** efficiency)

= (constant over 6 hours) X 1/5 X (14%)

**System efficiency = (Basic cell conversion eff) X (packing factor) X (power condition eff) X (overall loss eff)

= (21%) (85%) (90%) (90%)

TABLE C-32. RATE OF PHOTOVOLTAICS IMPLEMENTATION [NSF/RANN - 73]

Year	Peak Power Output Capability of Arrays Produced in One Year (MW)	Cumulative Output (MW)
1981	1	1
1983	10	13
1985	1,000	1,100
1990	5,000	10,000
1995	10,000	40,000
2000	20,000	100,000

by two or three orders of magnitude and work towards a manufacturing capability that literally brings sand in one door and ships solar cells out another. An interesting concept in this regard is the "solar breeder" described by Lindmayer [Lindmayer - 74] in which a solar cell plant expands about itself, deriving more and more power from its own cells to expand manufacturing capability until it is energy independent and producing great quantities of "excess" cells for the market.

Expansion will also require continuing cooperation from electric utilities to overcome the problems associated with the connection of a basically DC source to existing AC grids. Financial support is of great concern. While many utilities are currently providing some financial support for solar research through EPRI, they must eventually take a more active part by providing physical support for Federally funded POCE's. There is a unique problem in the solar cell industry. To reduce prices, volume must expand by orders of magnitude, but the market is waiting for lower prices - an endless loop. The government must break the loop by funding several large (one to ten MW) photovoltaic POCE's thereby bringing cell manufacturers to a high production level.

Impacts

The use of solar electric power generation suggests some interesting impacts; the major ones are mentioned here. Since solar/thermal and photovoltaic impacts overlap to a great extent they are discussed together.

The impact of expanded solar usage on existing utilities are likely to be fairly mild because the expansion will probably be quite gradual and orderly. However, since a new technology is involved, adjustments in thinking and planning will be necessary. The marriage between solar and conventional generation could be a good one from the outset. The solar/coal hybrid mentioned earlier in this section can greatly reduce coal consumption during daylight hours. Also, solar plants connected into existing grids could provide the peak shaving currently being done with gas turbines and the like. Later, as thermal storage methods develop further, stand-alone solar plants capable of 24-hour operation will be feasable.

Impacts on the labor market should be mild. Fabrication of solar cells, for instance, is not labor intensive. Construction of solar plants of either type will require only very conventional worker skills. Engineers will constitute a higher percentage of the total manpower requirement than for most energy related industries, but no forecasts have been attempted.

The diffuse nature of solar energy allows the generation of solar power to be widely distributed. The 100 GW capacity suggested for the year 2000 in the previous section would involve roughly 450 square miles, but this will not be sited on a single 21 mile square. There are several advantages to a distributed source. Transmission line losses are reduced, the need for more transmission line corridors is eliminated, and individual plant failures are felt only locally. Also, there may be a positive

social impact associated with decentralized power sources. The tax and cost structure and responsibility associated with smaller, local power plants provide a healthy social climate and a feeling of "oneness", belonging and pride in the community. The size distribution of American cities shows a great many communities of 10,000 to 13,000. If average solar insolation figures are used, a solar plant (photovoltaic or thermal) of about 0.1 square miles and some form of storage (batteries, flywheels, electrolysis/fuel cells or thermal) could supply all the electrical power needs for a community of 12,000. This corresponds to an average power demand of about 7 MW day and night, summer and winter. Clean air is especially desirable in residential areas. By using localized solar power plants near these areas, pollution from power generation would be completely eliminated. In defense of the existing centralized utility operation it should be noted that operating costs usually go up with decentralization. On the other hand savings in transmission line and conventional fuel costs may offset the higher operating costs.

Coal and nuclear power currently constitute the main sources of electrical power in the U.S. There is concern over various types of pollution associated with each of these. The only obvious pollution attributed to solar power plants would be the release of waste heat into the atmosphere. Solar/thermal plants, like coal and nuclear, have a thermal efficiency of only 30 to 40 percent. The amount of net atmospheric heating is less with solar plants however, because much of the waste heat is energy that would have been absorbed by the earth had the solar plant not been built. Thermal pollution may be less of a problem for photovoltaic plants because some of the unused energy is reflected. As with any system which alters the thermal balance in a region, there is the possibility of weather modification [Meinel - 72]. This effect would be minimized by distributing solar plants, rather than attempting to cover thousands of square miles of desert with one huge collector array.

Land use is perhaps the major impact associated with solar power. Because solar energy is so diffuse, large tracts of land are required for generating significant quantities of electrical power. At presently attainable conversion and land use efficiencies about 200 MW (peak) per square mile may be expected over the southern half of the U.S. Thus a 1.0 GW_e plant would require a total of five square miles, considerably more than for a comparable coal fired or even a nuclear plant. (But for coal and nuclear plants, mining and processing operations must also be included in a land use comparison The upper theoretical limit for conversion and land use efficiency would correspond to something less than 500 MW_e per square mile for solar power plants.

C-2 SYNTHETIC FUELS

C-2-1. COAL GASIFICATION

Present Situation

At least twelve companies have announced plans to construct coal gasification plants in the near future. The earliest of these will be based on the Lurgi process with an added methanation step to boost the BTU content of the SNG [GSR - 74]. Later plants will utilize newer processes such as HYGAS, BIGAS, SYNTHANE, and CO_2 Acceptor. Though not as efficient as the newer second generation gasification processes, the Lurgi process is not severly outmoded. The justification for building new plants which utilize old technology is twofold [MIT-74]. The Lurgi process has been in use for years and there is a high probability of attaining trouble-free plant operation very quickly. Also, in an inflationary economy it may be cheaper in the long run to build old technology today than to build newer technology a few years from now.

TABLE C-33 shows approximate dates of beginning operation for announced gasification plants. Also shown is cumulative SNG capacity through 1989. The rapid expansion shown in the table may be somewhat optimistic since plants were planned independently and ignored possible material and manpower shortages.

Unit Requirements

A proposed 250 million cubic feet per day (MCFD) SNG plant [OGJ - 73, Wooten - 74] for which construction is to begin in early 1975 is examined from three points of view: (A) operating material balance including waste products, (B) capital and operating costs, and (C) material and construction and operating manpower requirements. These requirements are probably representative of later construction utilizing newer processes. TABLE C-34 shows the major elements in an input/output material balance.

TABLE C-34 is based on coal typical of the Four-Corners Area near the San Juan River where the first plant has been sited. In addition to the coal used to feed the gasifier, 3,760 tons are required to fire the steam boiler which is not reflected in the output. Thus, waste gases and ash figures are actually higher than shown. Other materials (per year) needed include 1.46 million gallons methanol, 11,160 tons sulfuric acid, 20,000 tons caustic and 60,600 tons limestone.

The cost of a 250 MCFD plant is estimated at $406 million plus $59 million for the accompanying mining facility (1973 dollars). Operating and maintenance costs begin at about $56 million per year initially, increasing about 3.5 percent per year. The cost of service for the SNG is projected at $1.30 per million BTU at the plant.

TABLE C-33 PROJECTED DEVELOPMENT
OF COAL GASIFICATION CAPACITY

Year	Added Capacity MCFD	Cumulative Capacity MCFD
1978	250	250
1979	250	500
1980	830	1330
1982	500	1830
1983	500	2330
1984	500	2830
1986	750	3580
1988	250	3830
1989	500	4330

TABLE C- 34 SNG PLANT OPERATING MATERIAL BALANCE

Inputs		Tons/day
Coal		21,860
Water		25,160
Oxygen (cryogenic air separation)		5,680
	Total	52,700

Outputs		Tons/day
Ash		5,876
Evaporated Water		16,547
Recycled Water		3,730
Waste Water		1,921
Tar, Tar oil, Naphtha		1,475
Crude Phenols		105
Ammonia		183
Carbon Dioxide (vented)		17,223
Sulfur		200
SNG		5,440
	Total	52,700

TABLE C-35 itemizes the equipment and materials needed for plant construction.

Construction and testing of the gasification plant and coal preparation plant will require three years and 16,550,000 manhours. The peak labor force will be 3000 which includes about 250 engineers. Plant operation will require 612 employees and coal mining and preparation plant operation an additional 400. The plant site requires 400 acres of land. Based on the heating value of the product SNG, the overall thermal efficiency of the plant is 69.4 percent.

Path Requirements

Path requirements for the three selected paths are summarized in this section in terms of the material, manpower and cost of generating the prescribed amounts of substitute natural gas from coal. The requirements are presented in terms of numbers of Lurgi plants and are based on the following assumptions

> Plant output is 250 million cubic feet of SNG per day, 333 days per year
>
> Engineers constitute 8 percent of the total construction and operating work force
>
> During plant construction, expenditures and material needs are a linear function of construction time.

NEE. TABLE C-36 displays the NEE SNG requirement both in terms of Quads and numbers of COG and Lurgi plants. The rationale for splitting the SNG requirement is that the synthetic liquids requirement is first met using COG plants which also produce some SNG. The remainder of the SNG is then generated by Lurgi plants.

The capital, manpower and primary materials necessary to build the Lurgi plants specified in TABLE C-36 are given in TABLE C-37. The manpower requirements are in terms of total work force population at the end of each five year period. All other quantities are totals for the corresponding periods. For example, 1.3 million cubic yards of concrete are needed in the period 1985-90.

FTFB and AFTF. For the FTFB and AFTF paths, all SNG requirements are met using COG plants and those requirements are listed in the following section.

TABLE C-35 SNG PLANT MATERIALS LIST

Equipment	Quantity
Vessels	355
Heat Exchangers	315
Pumps	400
Fans and Blowers	22
Compressors	10
Tanks and Hoppers	87
Motors	509
Electrostatic Precipitators	6
Steam Boilers	3
Oxygen Plants	3

Materials	Quantity
Structural Steel	18,000 tons
Vessels, Steel	13,000 tons
Pipe Steel	11,000* tons
Conveying Equipment Steel	6,000 tons
Other Steel	12,000 tons
Steel for Mine Construction	40,000 tons
Concrete	70,000 cubic yards

*Does not include a 25-mile 42-inch pipeline for water nor a 67-mile 36-inch pipeline for SNG

TABLE C-36 . SNG REQUIREMENTS FOR THE NEE PATHS

	1985	1990	1995	2000
Required SNG, Quads/year	1.4	4.2	7.0	9.8
SNG from COG Plants, Quads/year	0	1.3	2.7	4.4
SNG from Lurgi Plants, Quads/year	1.4	2.9	4.3	5.4
Number of COG Plants Required	0	11	23	37
Number of Lurgi Plants Required	17	35	52	65

TABLE C-37 . LURGI SNG REQUIREMENTS FOR THE NEE PATH

	1975-80	1980-85	1985-90	1990-95	1995-2000
Capital costs, billions $	2.5	8.0	8.3	7.3	5.5
Engineering Manpower	2,000	3,800	5,200	6,200	6,700
Other Manpower	23,200	43,900	61,400	71,600	77,600
Steel, Millions of tons	0.5	1.7	1.8	1.6	1.2
Concrete, Millions of cubic yards	0.4	1.2	1.3	1.1	0.8
Methanol, Millions of gal.	0	60	190	320	430

Impacts

Some of the environmental impacts are apparent in the material balance table. Ash, waste water, CO_2 and sulfur are the major waste disposal products. Also, the 25,160 tons per day water requirement represents a continuous 5100 gpm flow which constitutes about one-fifth of the San Juan River. Note that a total of four plants are planned for this site which will nearly empty the river. Naturally, there are environmental concerns associated with strip mining the coal used in the SNG plant; these are discussed in Appendix B.

This and most other gasification plants will be sited in remote areas. There are serious social impacts associated with a temporary influx of 3000 construction workers into small communities which must be considered.

C-2-2 COAL TO MIXTURES OF FUELS

Present Situation

It is possible to convert coal into mixtures of attractive fuels. These include low-BTU (310-350 BTU/SCF) fuel gas, intermediate-BTU (600-800 BTU/SCF) fuel gas, substitute natural gas (1065 BTU/SCF), liquefied petroleum gas (4.23 x 10^6 BTU/bbl), ash-free solvent refined coal (15,600 BTU/lb with less than .7 weight percent sulfur), naptha, fuel oil and oil refinery feedstock (5.74 x 10^6 BTU/bbl). The exact amounts of each product depend on the plant design [Cochran-73]. The development of plants to achieve coal conversion is under the direction of the Office of Coal Research . Pilot plant studies of the solvent refined coal (SRC) process and advanced processes to produce substitute natural gas, identified as the Bi-gas, Synthane, Hygas and CO_2 Acceptor processes, are underway. However, to date, no tests on any scale have been run for the simultaneous performance of the required process units to yield mixtures of fuels.

Unit Requirements

Entirely gaseous products are possible by coal conversion. The substitute natural gas (SNG) plants discussed in the previous section are an example of this technology. The production of low-BTU fuel gas for use in COGAS units is another example. At the opposite end of the spectrum of fuel mixes, a demonstration plant is planned which will produce only liquid product, a mixture of approximately #6 and #4 fuel oils. The projected efficiency is 63.5 percent [RMP-73]. For production of liquids from coal, this is judged to be unacceptably low.

To achieve liquids from coal at higher efficiency, it is necessary to produce a mixture of gaseous and liquid products. An example of a highly efficient coal conversion plant is the Coal-Oil-Gas (COG) refinery. A conceptual design and economic analysis have been performed for a COG refinery to produce 100,000 bbl/day of oil refinery feedstock and other products from 57,700 tons/

day of Midwest coal. A summary of material and energy balances is shown in TABLE C-38. The oxygen needs of the plant are met by on-site air separation facilities fueled by part of the plant's share of solvent refined coal. The thermal efficiency of the refinery, defined as the heating value of saleable products divided by that of the input coal, is 75 percent [Frank-72]. An estimate of the cost of this refinery in 1971 dollars was \$587.2 x 10^6 plus an engineering fee of \$17.8 x 10^6. Included in the plant cost is \$188.1 x 10^6 for purchased equipment, \$101.2 x 10^6 for design and construction, \$172.2 x 10^6 for materials and labor and \$12.8 x 10^6 for initial catalysts. The refinery requires 280 operating personnel [PM-72]. No detailed breakdown of skilled labor requirements or basic construction materials is available. Rough estimates from the detailed capital requirements give \$86.1 x 10^6 for construction materials, 70 x 10^6 man-hrs of construction labor and 1500 man-yrs of design effort.

Path Requirements

As explained above, producing liquid fuels from coal using a COG refinery also yields some substitute natural gas. The Nuclear Electric Economy is the only energy future of the three analyzed which calls for specific amounts of synthetic liquids and gases. In this case, the difference between the gas required and that produced in the COG refineries is made up by SNG plants. Details of the requirements for the SNG plants needed to produce this gas are presented in the previous section. The Ford Technical Fix futures, both the base and the alternate cases, do not call for synthetic fuels. In light of present development efforts, however, allowance is made to bring several commercial COG refineries on line by 1990 and operate them for experience. This is a conscious effort to keep all options open at the year 2000 as suggested by the National Academy of Engineering [NAE-74]. TABLE C-39, shows the number of COG refineries for the cases analyzed at five year intervals beginning in 1985 until 2000. Also, operation and construction requirements are set forth.

Impacts

A single COG refinery would consume nearly 20 x 10^6 tons of coal and 6.7 x 10^9 gallons of water annually. Such an appetite would demand siting of the plants at minemouth locations with adequate water supplies. However, only .4 x 10^{15} BTU of liquid and gaseous hydrocarbons are produced. The waste products include .6 x 10^6 tons of elemental sulfur and 1.4 x 10^6 tons of ash for the coal of TABLE C-38. Moreover, additional refining of the liquid products is required to yield oil products.

The impact of the many COG refineries needed for significant amounts of synthetic fuels is not analogous to that of electrical generating plants using comparable amounts of coal and water. As the name COG refinery suggests, these are chemical processing plants and would be expected to make impacts similar to oil refineries. Until further development yields data on the simultaneous performance of the required process units, amounts of actual plant emissions are not available. This technology for producing hydrocarbons from coal seems best suited for production of petrochemical feedstocks and synthetic gas for which no substitute fuel is possible.

TABLE C-38 OVERALL MATERIAL AND ENERGY BALANCE FOR A COG REFINERY

Coal Analysis: 3.38 Percent by Weight of Sulfur, 7.13 Percent Ash, 12825 BTU/LB

Feed to Plant	Tons/Day	BTU/Day
Coal to SRC	43,900	$1,126 \times 10^9$
Coal to Bi-Gas	13,800	354×10^9
Water Consumed in Processing	15,619	--
Makeup Water for Cooling	69,120	--
Oxygen for Bi-Gas	7,739	--
Products from Plant		
Carbon Dioxide	39,333	--
Sulfur	1,805	14×10^9
Pipeline Gas	7,658	354×10^9
Liquefied Petroleum Gas	1,979	87×10^9
Oil Refinery Feedstock	14,660	574×10^9
Solvent Refined Coal (For Plant Fuel)	8,845	277×10^9
Solvent Refined Coal (Product)	2,480	78×10^9
Phenol, Cresols, Xylenols	156	--
Ash	4,142	--

TABLE C- 39

COG REFINERY REQUIREMENTS FOR SELECTED FUTURES

	Annual:					Five-Year:		
	Units	Coal (T x 10^{-6})	Water (GAL x 10^{-9})	Engineers	Non-Engineers	Steel (T x 10^{-6})	Concrete (yd^3 x 10^{-6})	Funds (1974 \$ x 10^{-9})
1981-1985:								
NEE	0	0	0	6000	69,000	1.5	1.7	3.7
FTF	2	39	14	660	7,600	.22	.25	.5
1985-1990:								
NEE	11	212	75	7500	87,000	3.1	3.6	7.8
FTF	6	115	41	2080	24,000	.68	.78	1.7
1991-1995:								
NEE	23	442	156	8500	98,000	3.5	4.0	8.8
FTF	7	135	47	1050	12,000	.76	.87	1.9
1996-2000:								
NEE	37	712	251	9300	107,000	3.9	4.5	9.8
FTF	7	135	47	160	2,000	.14	.16	.3

C-2-3 GAS FROM WASTE

Present Situation

At the same time that the U.S. has begun to consume fossil fuels in greatly increasing quantities, it has also begun to produce solid wastes in tremendous quantities. A great deal of experimental work has indicated that some of these wastes can be converted to synthetic fuels, thereby contributing to the solution of the energy crisis. While it is clear that conversion of wastes to fuels is not a feasible means of averting the crisis, it can contribute small quantities of oil and gas to domestic supplies (and can be burned directly) and it does simultaneously dispose of those undesirable wastes.

About 2 billion tons of solid organic wastes are produced each year. Only about 880 million tons of this is useable and more than 80 percent cannot be economically available. This amounts to about 136 million tons of dry organic wastes readily collectible for conversion.

Four methods are used or under development to produce energy from solid organic waste: (a) direct incineration, (b) by hydro-generation, (c) pyrolysis, and (d) anaerobic digestion. The output for the first three methods are summarized in TABLE C-40.

There is a growing interest in the bioconversion area. Bioconversion can be applied to both solid wastes and solid organic wastes. The estimated volume of solid waste (not including organic solid waste) currently being generated by the U.S. population is equal to approximately 5 pounds per person per day, or about 182 million tons per year. It is estimated that by 1980 this burden will increase to an estimated 260 million tons per year.

The biological conversion of solid wastes to fuel gas is being researched by a group at Dynatech (Wise-74). Calculations of the proportion of methane available through conversion of suitable solid waste (58 million tons/yr (32% of total) may be digested) show that 0.8 trillion cubic feet of methane is available. Thus, the fuel available from waste could furnish about 4% of the fuel gas demand. [Wise-74]

In the next section the estimated capital cost for building and operating such a plant are presented.

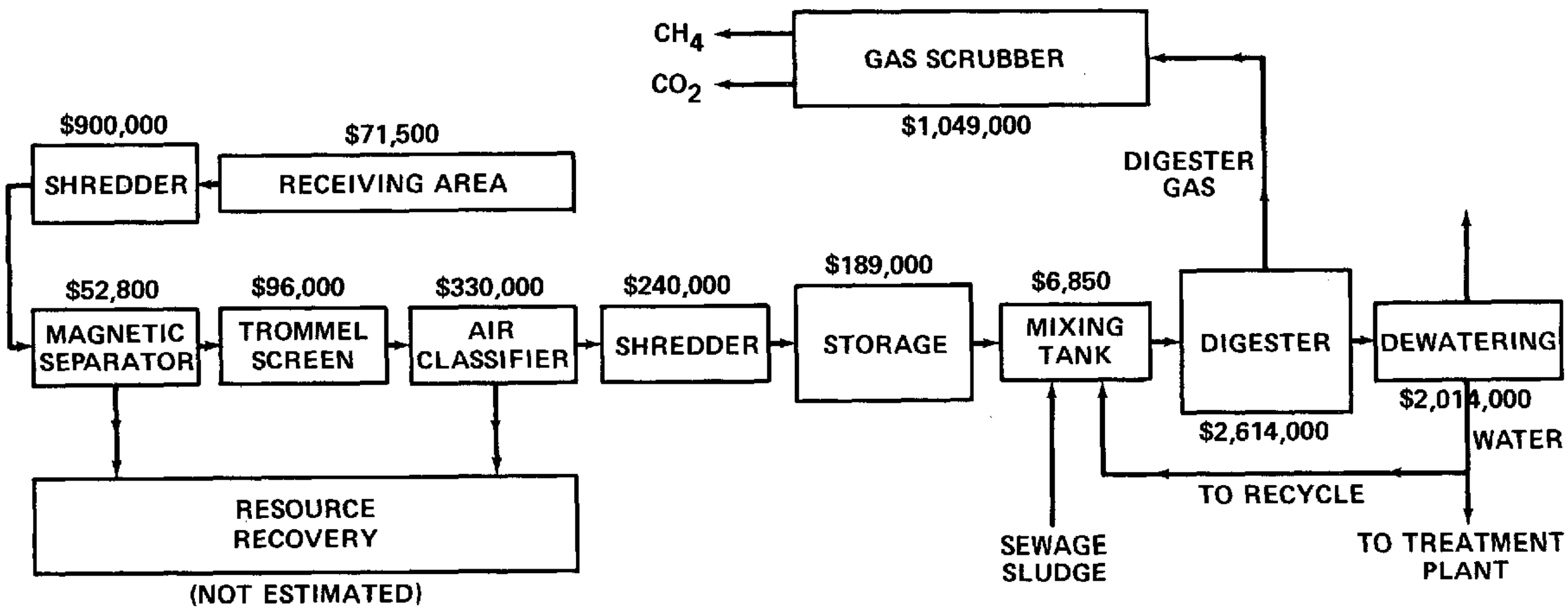
Unit Requirements

An estimate of the cost of various components in the conversion of solid waste to methane is presented in FIGURE C-11 and the basis for calculating capital costs is displayed in TABLE C-41. A breakdown of the operating costs is presented in TABLE C-42.

TABLE C-40 FUELS FROM SOLID ORGANIC WASTES*

Method	Output	Energy Value
Direct incineration	--	$3\text{-}8 \times 10^3$ BTU/lb
Hydrogeneration	1.25 Barrels/ton	1.5×10^4 BTU/lb
Pyrolysis	1 Barrel/ton Some Gas	1.05×10^4 BTU/lb $4.0\text{-}5.0 \times 10^2$ BTU/scf

*Data compiled from SCIENCE, pp. 599-602, Nov. 10, 1972.



ADDITIONAL CAPITAL COSTS:

PUMPS AND PIPING = $120,000
INSTRUMENTATION = $200,000
BUILDING = $500,000

FIGURE C-11 TOTAL CAPITAL COSTS FOR THE WASTE DIGESTION PROCESS
CAPACITY: 1000 TPD MUNICIPAL WASTE, AS RECEIVED [Wise-74]

TABLE C-41 BASIS FOR CALCULATING TOTAL CAPITAL REQUIREMENT [WISE-74]

TOTAL PLANT INVESTMENT	
ALL ONSITE PLANT SECTIONS	$ 8382457
ALL UTILITIES AND OFFSITES	
CONTRACTORS OVERHEAD AND PROFIT	1760316
ENGINEERING AND DESIGN COSTS	502947
SUBTOTAL PLANT INVESTMENT	$ 10645720
PROJECT CONTINGENCY (.15 SURTOTAL PLANT INVESTMENT)	1596858
DEVELOPMENT CONTINGENCY (.07 SURTOTAL PLANT INVESTMENT)	745200
TOTAL PLANT INVESTMENT	$ 12987779
INTEREST DURING CONSTRUCTION (INTEREST RATE X TOTAL PLANT INVESTMENT X 1.875 YEARS)	2191688
STARTUP COSTS (.02 TOTAL GROSS OPERATING COST)	75403
WORKING CAPITAL	
RAW MATERIALS INVENTORY	
MATERIALS AND SUPPLIES	
NET RECEIVABLES	48066
TOTAL CAPITAL REQUIREMENT	$ 15302935

TABLE C-42 BASIS FOR CALCULATING GROSS AND NET OPERATING COST [WISE-74]

(.90 PLANT SERVICE FACTOR)

RAW MATERIALS	$	0
CATALYSTS AND CHEMICALS (LIME AT $25/TON)		8012
PURCHASED UTILITIES		
ELECTRIC POWER ($.0100/KWH)		155758
RAW WATER ($.02/1000 GAL)		10636
HEAT ($1.0/MILLION BTU)		190424
LABOR		
PROCESS OPERATING LABOT (16 MEN AT $5.63/HOUR)		249344
MAINTENANCE LABOR (12 MEN AT $5.63/HOUR)		187008
SUPERVISION (4 MEN AT $6.63/HOUR)		73408
ADMINISTRATION AND GENERAL OVERHEAD (.60 TOTAL LABOR)		305856
SUPPLIES		
OPERATING (.30 PROCESS OPERATING LABOR)		74803
MAINTENANCE (.015 TOTAL PLANT INVESTMENT)		194817
LOCAL TAXES AND INSURANCE (.027 TOTAL PLANT INVESTMENT)		350670
DISPOSAL COSTS		
CAKE ($30/TON DRY SOLID)		1845423
WASTE WATER ($.20/1000 GAL)		9729
INORGANIC MATERIALS ($1.25/TON)		114272
TOTAL GROSS OPERATING COST (PER YEAR)	$	3770159
CREDITS		
FRESH WASTE ($10.65/TON)		(3513094)
SEWAGE SLUDGE ($50/TON DRY SOLID)		(618502)
SCRAP IRON ($17/TON)		(343195)
TOTAL NET OPERATING COST (PER YEAR)	$	-704632.00

AVERAGE GAS COST. $/MILLION BTU = .987

The total heat required to operate the plant is estimated to be 2.4×10^7 BTU/hr; and the time-averaged total power required is about 2636 HP. Approximately 144,600,000 BTU/hr of methane will be produced in the process which has a capacity of 1000 tons per day municipal waste. At 85% thermal energy recovery and 30% conversion to mechanical energy, the ratio of energy required to drive the process to energy generated equals 0.350. [Wise-74].

A pilot plant that will process 1.7 tons per day, defined in terms of raw, as received waste, is estimated to have a total budget of $718,821.

C-2-4 GAS FROM KELP

One bioconversion method currently under investigation by Dr. Howard Wilcox and Dr. Wheeler North is the fermentation of kelp. The MARINE FARM PROJECT is a three phase program designed to establish by 1985, an operating "demonstration" marine farm system covering 100,000 acres of open ocean area.

Phase I, currently estimated to cost about $3 million, will cover a two-year period and is devoted to studying and establishing the basic feasibility of all concerned processes and cost through installation and operation of one 7-acre marine farm (MF) in the Pacific Ocean and another similar MF in the Atlantic Ocean.

Given the successful completion of Phase I and the decision to proceed, Phase II would establish within 4 years a 1,000-acre MF in the Pacific and in the Atlantic Ocean at a cost of about $48 million.

The final phase covering a five-year period would establish a 100,000 acre farm in either the Atlantic or Pacific Ocean at an estimated cost of $2 billion.

Present Situation

An initial $250,000 project to analyze both theoretically and experimentally the potential benefits and costs of a system of large marine energy farms is already underway.

The initial "baseline" design of the marine farm involves a horizontal mesh of lines or cables disposed some 40 to 80 feet below the ocean's mean surface. This mesh with the attached kelp would be rendered approximately neutrally buoyant and would be anchored to the bottom by appropriate moors or else slowed towed by an appropriate ship. The farm would support some 436 kelp plants attached to the mesh by their "holdfasts".

The concept calls for harvesting by an appropriate number of specially designed ships or barges. This fleet might also carry and dispense whatever fertilizer compounds may be needed or desired for increasing the yield of the farm. Alternatively, forced upwelling of cool, rich deep water may provide satisfactory fertilization of the farm at reduced cost.

Regarding the harvesting system, Kelco presently operates three ships of approximately 500 tons each to harvest 50 mi^2 = 32,000 acres @ yield

1/10th per acre of what we expect to realize. Hence we could expect to require 30 times as many ships, or 45,000 tons of ships. At $200M for the system, this comes to about $4500 per ton, which appears reasonable.

Dr. Wilcox thinks that 350-500 wet tons of kelp can be obtained from one acre in one year by cutting the top six feet of the kelp 3 or 4 times a year. Approximately 40 tons of dry solid can be obtained from this amount of wet kelp. However, the kelp will not be dried. Instead a sea water slurry will be introduced into the digester (fresh water will be used if necessary). The digester is a large vat at a temperature of about 40° C. The anaerobic digestion takes place as described above. The Kelp is first converted to acids, mainly acetic acid, then the acid-consuming organisms convert the acid to methane and carbon dioxide. Standard separation technieues will be used to separate the CH_4 and CH_2.* The fermentation process takes 5-12 days to obtain the optimum quantity of methane. One acre of kelp should yield about 1.6×10^5 s.c.f. of methane per year. In addition to the methane, the sludge is rich in phosphate and nitrate and therefore will be valuable as a fertilizer and it can also be used as animal feed.

The food, fuels and petrochemical conversion facility, visualized as a large facility which is shore-based or else floating, would be required to accommodate material equivalent and moored by suitable anchors, to 4×10^8 Btu/ac.yr or $4 \times 10^{13} \frac{\text{Btu}}{\text{yr}}$ in toto. This is a "power" magnitude of about 1.4×10^6 kw. If the cost of the facility is $500M, the "cost per Kw equivalent" is about $360, which appears reasonable. Start-up operations, which are estimated to cost $400M for one year, would employ about 8000 men, direct labor, assuming $50,000 per man-year including overhead. This is 8 men per 100 acres, which seems reasonalbe.

* A different type of yeast can be used in the fermentation process to obtain methanol.

C-3. SOLAR ENERGY: HEATING AND COOLING OF BUILDINGS

Solar energy is manifest in many forms, each having been examined in varying detail to discover new and usable energy sources. It is generally agreed that space heating and cooling and hot water heating is the most likely area for solar energy to make a genuine and immediate contribution in the overall energy picture. This section is an overview of that subject describing the current status of solar heating and cooling, typical requirements for several representative types of solar energy systems, and the requirements and impacts of introducing a solar industry into the U.S. economy.

C-3-1. PRESENT SITUATION

Solar heating and cooling has received considerable attention in recent years as summarized in TERRASTAR [TERRASTAR - 73]. During the past year the National Science Foundation has sponsored three independent solar heating and cooling studies by TRW, Westinghouse and General Electric. At this writing two of these studies [TRW - 74, Westinghouse - 74] are available and are reflected in the contents of section C-3 together with other sources.

There are three main types of solar energy systems: hot water heating, hot water and space heating, and hot water and space heating and space cooling with several variations of the latter. In most current studies, these systems have several things in common:

1. Each system uses flat plate (non-concentrating) solar collectors with either water or air as the coolant.

2. Each system uses some form of energy storage, usually water with water coolant or crushed rock with air coolant.

3. Each system utilizes an auxiliary energy source to maintain service during periods of extended cloudiness or extreme cold.

The only solar energy systems in use today are those which are economically competitive with low cost fossil fuels, because only recently has there been incentive to use solar energy. Solar water heaters are used in several sections of the U.S. and in other countries. With few exceptions, the only solar heating and cooling systems in operation are a number of Proof-of-Concept-Experiments (POCE's) sponsored by various organizations. These POCE's have demonstrated that solar units are a viable alternative to conventional units. The technology exists and is proven.

Rapid expansion of solar usage is limited by present energy economics (which are rapidly changing) and by the absence of a functioning solar energy systems industry. These limitations are discussed in more detail in section C-3-3.

C-3-2. UNIT REQUIREMENTS

Many different types of solar energy systems for heating and cooling buildings have been investigated. Indeed, in a given locality for a given building one type will be superior to others. Part of the cost minimization involved in a design is the choice of a system type, trade-offs between the amount of collector surface area, storage capacity and auxiliary fuel use, and so on.

For the purposes of this study, however, it would not be useful to enumerate the unit requirements for many different types of units because the future market breakdown in terms of building types and geographical location is unknown. For this study, the use of solar energy for space heating and cooling is adequately described by incremental units of energy per year. This can in turn be equated to square feet of collector in service if the following assumptions are made.

> The average solar insolation over the U.S. is 200 watts/m^2 (560,000 BTU/ft^2/year), day and night, summer and winter.
>
> Flat plate blackened collectors utilizing a liquid medium for heat transfer and two glass panes are used and a steel tank is used for storage. Essentially all the incident radiation is utilized which implies that the collector vertical tilt angle is optimally adjusted.

Table C-43 summarizes the major material, cost and manpower requirements necessary to manufacture and install one million ft^2 of collector. The materials list does not include pumps, control circuits and other small quantity items which do not represent major portions of any industrial sector. The cost shown is an average of the various types and sizes of solar energy systems completely installed at today's prices. The manpower figure is an estimate which includes panel manufacture and complete system installation.

In the past, conventional systems (fossil fueled) have been designed using worst-case assumptions. At the present time, solar systems capable of providing 100 percent of the year-round heating and cooling needs are expensive because of the large collector area and storage capability required. To be economically competitive, solar systems must become hybrid systems utilizing an auxiliary (fossil or electric) source for a small percentage of the time. There is an optimal balance between all solar and all auxiliary where amortized system cost is minimized as suggested by Figure C-12. Note that the minima are very broad, indicating that an extremely accurate analysis is not necessary. As a rule, minimum cost occurs at about 10-15 pounds of water storage per square foot of collector area, which corresponds to one to three days of heat storage. A similar analysis could be conducted for air/rock storage systems. Computer programs have been written to aid in system design (references 3.4-4, 5, 6 in [TRW-74]).

C5

TABLE C-43. - SOLAR ENERGY SYSTEM UNIT REQUIREMENTS PER MILLION SQUARE FEET OF FLAT PLATE COLLECTOR

Item	Quantity
Aluminum	400 Tons
Glass	1,000 Tons
Insulation	150 Tons
Steel	1,000 Tons*
CPVC Pipe	100 Tons
Cost	$11 Million
Manufacturing Manpower	60,000 Manhours
Installation Manpower	120,000 Manhours
Useful Energy generated per year	.00056 Quads

*Fiberglass tanks could also be used; price is approximately the same.

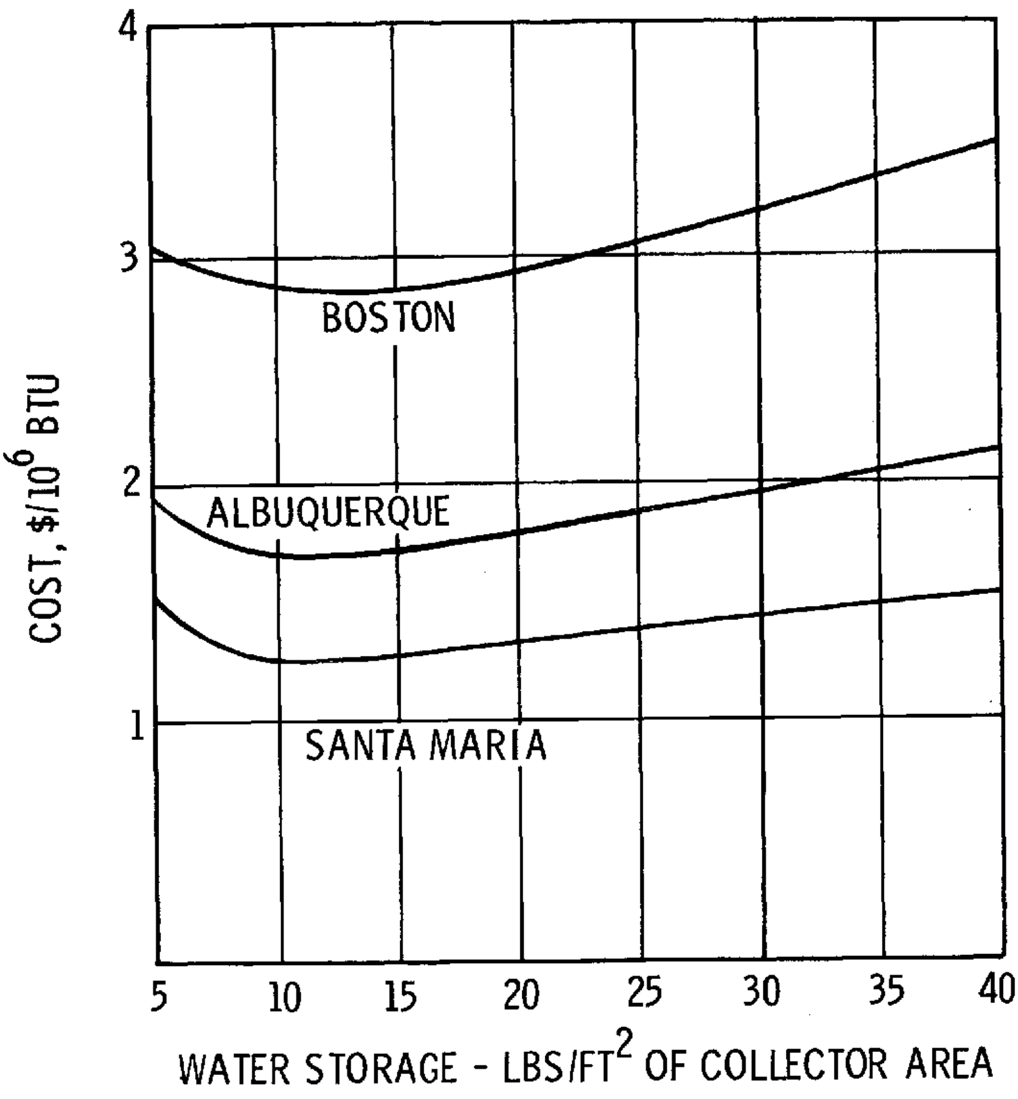


FIGURE C-12 HEATING AS A FUNCTION OF THERMAL STORAGE CAPACITY FOR A 25,000 BTU D D HOUSE [TRW-74]

C-3-3. EXPANSION REQUIREMENTS

The "do-nothing" future of solar energy system use in the U.S. is projected in Figure C-13 . The assumptions used to create this figure are a 5% wage inflation, 2.5% cost reduction for solar equipment, and 7% conventional energy cost growth, all yearly percentages. To interpret the figure, in 1985 about 85% of new buildings will be situated such that solar systems will be cost competitive with conventional systems. About one-sixth of that block (in dollars) will be schools, and about one-eighth will be single family dwellings. If the same assumptions hold beyond 1985, conventional systems begin to lose in all segments of the building industry. Note that only new buildings are involved in Figure C-13 ; retrofitted solar systems are economically less attractive than for new construction. But in an economic climate favoring solar usage, the retrofit market could be substantial.

The present slow trend toward solar systems could be accelerated by providing incentives and by working to achieve a favorable economic climate. Government incentives can act to reduce the effects of high solar system capital costs, increase the operating cost advantage and minimize the tendency of financial and insurance institutions to oppose new technology. The following are suggestions which may accelerate the growth of solar industries:

Provide income tax credits for solar systems.

Sales tax exemptions on solar equipment purchases.

Increase availability of mortgage money; guarantee and insure loans for solar systems.

Allow faster depreciation on solar equipment for tax purposes. (Five-year amortization is allowed on pollution control facilities, why not for solar systems?)

Provide federal and state research and development money.

Remove price controls on fossil fuels and Uranium and let them find natural levels in the market place.

Provide the means (possibly through the National Bureau of Standards or the National Weather Bureau) for establishing an accurate climatic data base for solar system design. Accurate data for most of the country is not available.

Local government can encourage the use of solar energy systems by adjusting property taxes <u>downward</u> by the amount of the solar equipment purchase. Several states and counties are already doing this.

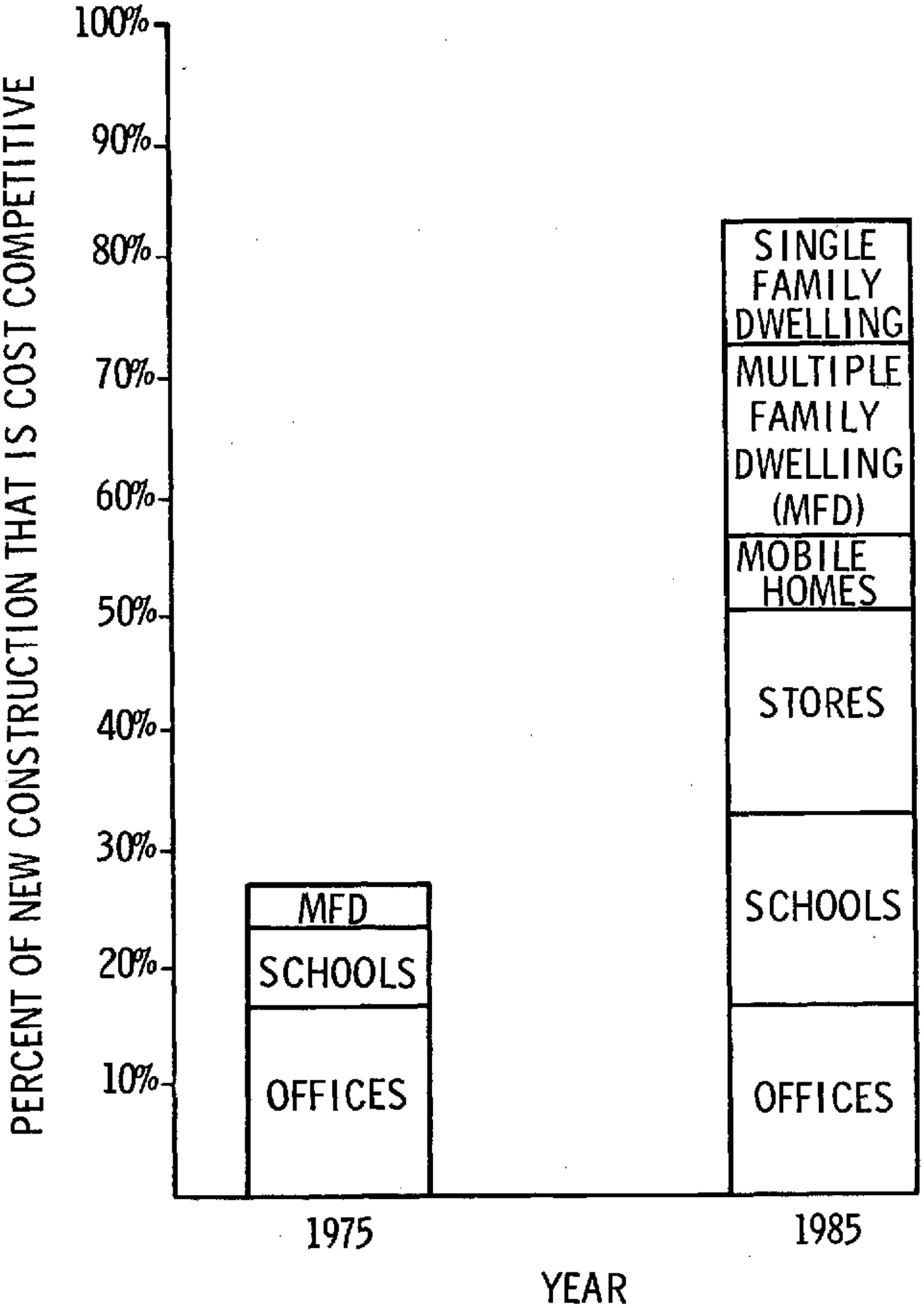


FIGURE C-13 TRENDS IN SOLAR-ASSISTED SPACE HEATING AND COOLING SYSTEMS COST-EFFECTIVENESS [Westinghouse-74]

Though these measures cost money, benefits derived therefrom yield national benefits greater than the cost in the form of savings of domestic fossil fuels, reduced pollution and improved balance of payments.

Utilities could remove an artificial price barrier by reversing the incremental rate structure which encourages industry to use more energy. Also, it may be that preferential electrical rates currently given to single family residences should be phased out.

C-3-4. PATH REQUIREMENTS

The expansion requirements discussed in the previous section are given in very general terms. The purpose of that section was to indicate the potential future of the solar energy industry. In this section specific requirements to meet the solar energy as prescribed by each of the three scenarios selected for analysis are given.

NEE Path

No solar energy usage is specified.

FTFB and AFTF Paths

The solar requirement time profile in Quads/year for the AFTF is given as the first row in Table C-44 . together with the manpower and material requirements for that path. No separate table is given for the FTFB path because the path requirements are almost identical. The assumptions used in generating this data are given in section C-3-2.

As an indication of the feasibility of expanding the solar heating and cooling industry as fast as these paths dicatate, consider Figure C-14. The AFTF solar requirement lies toward the bottom of a corridor formed by two estimates of solar industry expansion made in the TERRASTAR report [TERRASTAR-73]. The lower line represents a conservative "gradual phasing" plan; the upper line represents a "maximum effort" plan.

C-3-5. IMPACTS

The use of solar energy can be expected to have social, environmental and political impacts. Those which are specifically related to solar heating and cooling systems are summarized below.

Public Attitude. There have been at least two attempts to survey public attitude and acceptance of solar energy usage [TRW - 74, Westinghouse - 74]. The major findings are as follows.

TABLE C-44 . SOLAR HOME HEATING AND COOLING REQUIREMENT FOR AFTF AND FTFB PATHS

	1975-80	1980-85	1985-90	1990-95	1995-2000
Solar Quads/year	0.1	0.7	1.4	2.1	2.7
Ft^2 collector (billions)	0.1	1.2	2.6	3.7	4.8
Alunimum (thousand tons)	32	240	300	250	250
Glass (million tons)	0.1	1.1	1.4	1.1	1.1
Insulation (thousand tons)	22	160	200	170	170
Steel (million tons)	0.1	1.1	1.4	1.1	1.1
CPVC Pipe (thousand tons)	15	110	130	110	110
Cost (billions)	2	12	15	12	12
Engineering Manpower	200	1,800	3,700	5,300	6,900
Other Manpower	2,500	20,000	43,000	61,000	79,000

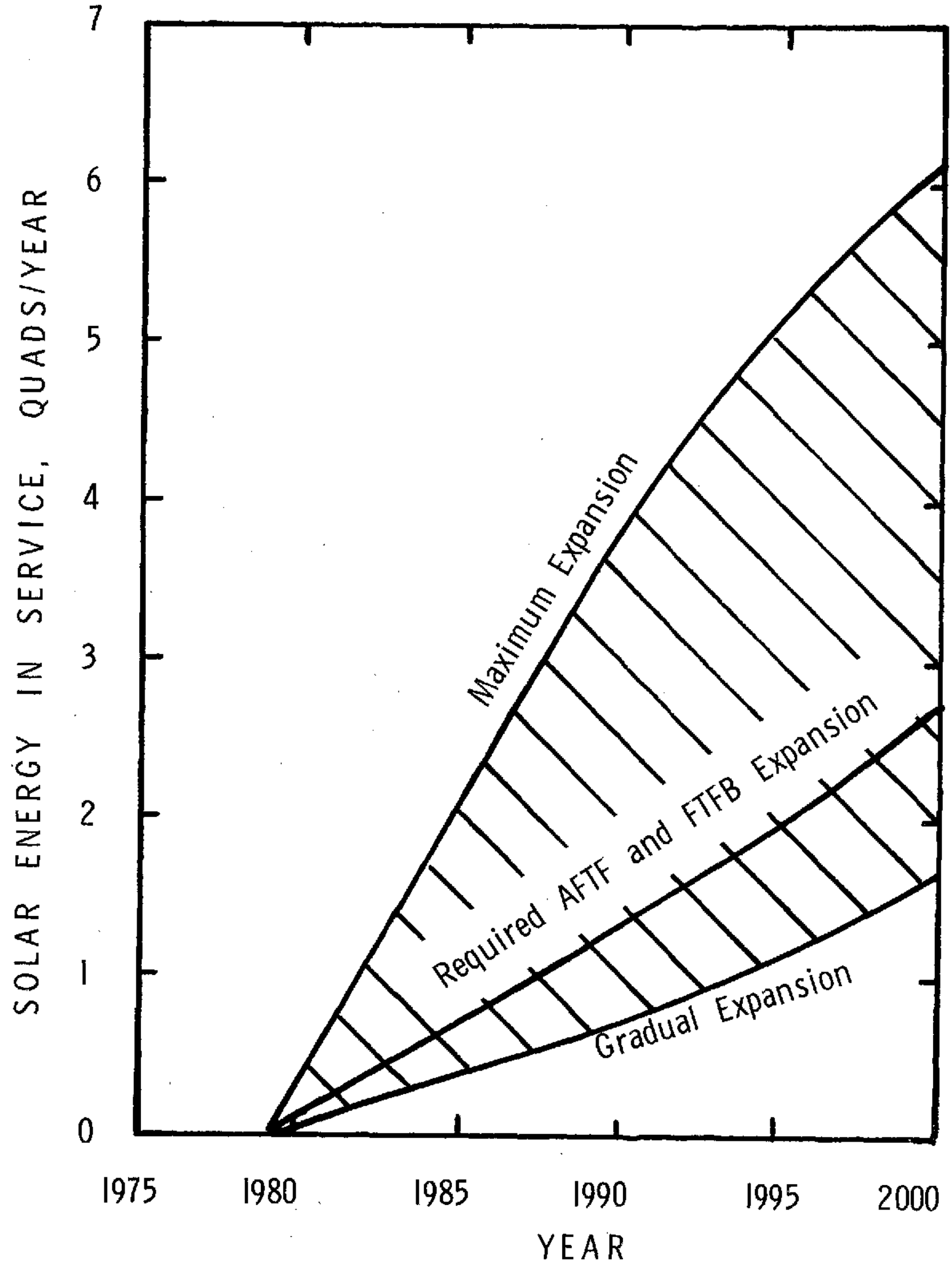


FIGURE C-14 COMPARISON OF SOLAR DEVELOPMENT: AFTF PATH REQUIREMENT, TERRASTAR ESTIMATES

The public is generally quite aware of solar energy and expects rapid development.

People seem willing to at least consider solar energy systems even though initial costs are higher than for conventional systems. High capital costs are much more acceptable in new homes and buildings than for retrofitting existing buildings. Additional capital costs for solar equipment up to perhaps $5,000 would be acceptable in newly built homes.

Solar collectors on (or part of) building roofs was almost totally acceptable.

Those more knowledgeable concerning solar energy had more positive attitudes toward its use.

A majority favored tax incentives or some other form of governmental support to encourage the use of solar energy.

The most attractive features of solar energy were low operating cost, availability of energy, the saving of dwindling fossil fuel supplies, and the fact that solar energy is nonpolluting.

The main objections were high initial cost and a concern over the storage problem.

Public optimism concerning the use of solar energy and individual willingness to use it were influenced by whether or not the energy crisis was perceived as being "real".

Some people picture solar energy only as a means of producing electricity to be fed into existing grids and not affecting them personally. Attention needs to be shifted from the more exotic uses of solar energy to individual uses. This is a clear indication of the need for widely dispersed POCEs to make the public aware of solar heating and cooling system potentials.

Utilities. The impact of solar energy systems on the utilities will likely be very small. Since the use of solar energy will increase so gradually it could do no more than slow the conventional energy supply growth rate. However, there is a long term concern as solar systems assume a larger percentage of the total market. Solar systems require a supplementary energy source to offset the need for storing large amounts of energy. Thus loads on the utilities may become excessive during long cloudy, cold periods unless fairly large standby capabilities are provided.

Energetics. Regarding the energy intensiveness of solar energy systems it has been determined that about 100,000 BTU of energy is required to manufacture one square foot of flat plate collector. Considering the average U.S. insolation and assuming maximum energy capture, solar systems can be expected to pay for themselves energy-wise in something less than one year. In fact the energy return over the life of the equipment compared with the energy invested in building the equipment is better for solar heating and cooling systems than for any of the conventional systems, including those powered by nuclear-generated electricity.

Manpower. Because the solar heating and cooling industry will expand so gradually, no manpower shortages or displacement problems are anticipated. The industry is attractive because it involves a non-depleatable energy source and will have a high degree of permanance. Moreover the industry will be widely dispersed which minimizes certain social impacts.

Materials. Materials used in manufacturing solar energy systems are relatively abundant. The only ones which do now or could in the future involve imports are aluminum and copper. Again, the predicted gradual growth of the solar industry tends to preclude material shortages and bottlenecks.

APPENDIX D. DISTRIBUTION OF ENERGY

D-1 INTRODUCTION

The basic purpose of energy distribution is to transport the energy from its source location to the location of end use. Under any choice of a future energy scenario, the determination of the requirements (manpower, capital, etc.) of the future distribution system or systems is quite difficult because both the source region and the end use region depend on the scenario. For example, in an economy geared to direct use of oil and petroleum products, the transportation facilities will be slanted toward pipelines and tankers with, for example, major units of transportation from Alaska to the West Coast and from the Gulf Coast to the northeastern states. On the other hand, a national economy heavily dependant on nuclear energy requires comparatively large investments in electric transmission lines spread around the country in an interconnected energy "grid". On top of these problems is the difficulty that the areas where energy use will grow most are likely to be different from the present largest energy use locations. In addition, the availability of energy in an area leads to increased energy use, within that area, and hence energy availability affects the distribution system. For example, the availability of large quantities of cheap hydroelectric energy at Hoover Dam led to the development of the first high voltage electricity transmission lines, and the combined system of generation and transmission made possible the early rapid growth in southern Claifornia. Another example of the interplay between energy availability and usage is seen in the Table D-1. Note that in the Gulf Coast region, where a large percentage of U.S. oil and gas reserves are located, the per capita use of energy is significantly higher than in other regions of the country.

Other difficulties of predicting the energy distribution system needs of a particular scenario can now be seen. For example, a scenario calling for a 50 percent increase in the use of oil need not necessarily require a total oil pipeline capacity increase of 50 percent, because the oil might be utilized closer to the production source, or there might be a shift in distribution, e.g., from pipelines to oil tankers.

In recognizing the problems described above, the task group on energy distribution has attempted to do two things. First, a general description of the unit costs of moving energy by the various means has been provided. These costs are summarized in Figure D-1, and additional commentary has been made, where appropriate, in the various appendix sections below. Second, estimates have been made of the total needs (capital, manpower, etc.) of the predominant energy distribution systems for the three paths chosen for the study in this report. In addition, a review and impacts study has been made in Appendix D-7.

TABLE D-1 ENERGY USE IN THE U.S. BY REGION
[CMB-1972]

Region	Population % of Total U.S.	Energy Use % of Total U.S.	Per Capita Equiv Oil Bbls/Year
East Coast	39	31	47
North Central	33	34	61
Gulf Coast	12	20	101
Rocky Mtn	2	3	69
West Coast[a]	14	12	51
	100	100	59

a) Includes Alaska and Hawaii

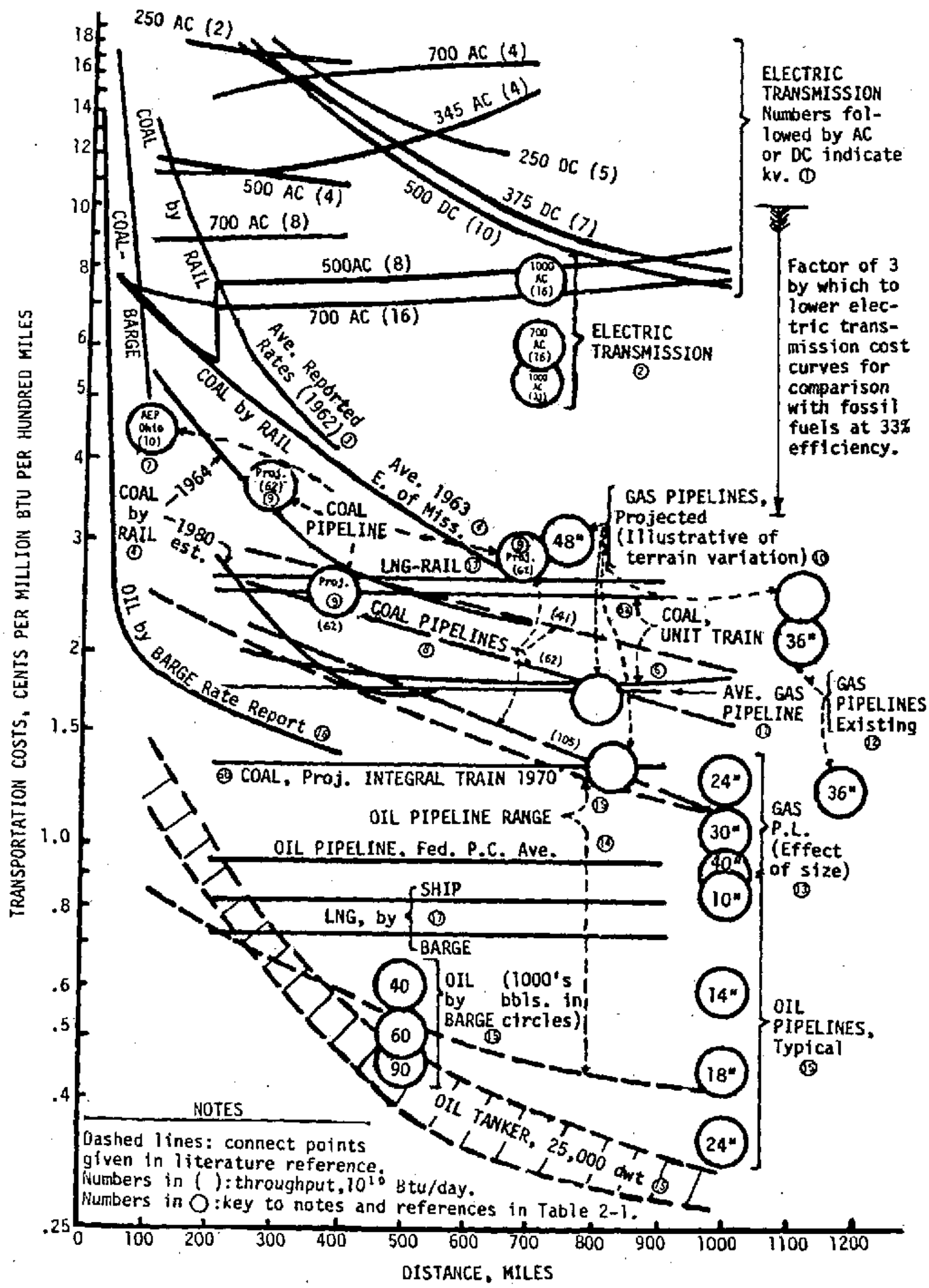


FIGURE D-1 COSTS OF TRANSPORTING ENERGY [Hottel-71]

D-2 NATURAL GAS, SUBSTITUTE NATURAL GAS, AND LIQUEFIED NATURAL GAS TRANSPORTATION

Most U.S. natural gas is presently moved within the lower 48 states through a pipeline system of 900,000 miles representing a gross investment of $46 Billion and serving approximately 150,000,000 customers. The American Gas Association predicts that, if adequate gas supplies are assured, gas companies will make an additional gross investment of the same size by 1990 [AGA-72]. Unfortunately, this figure is of relatively little value for this present study, since the scenarios for the future under examination here do not predict the same total gas use as does the AGA.

Gas pipeline construction in the future will, to a significant extent, be quite unlike present lines. Most present lines are on land within the lower 48 states. Future construction will be more heavily offshore, in collection systems; other major construction will be required, in order to move recently discovered gas on the north slope of Alaska. Construction of gas pipeline lines in the lower 48 states will become much more expensive, when construction unit costs are considered. In 1972, onshore pipeline costs averaged $245,000 per mile for 36" pipe, whereas offshore construction averaged $553,000 per mile [OGJ-73-1]. A better picture of the costs, better data for predicting expenses in the future, can be gained from the following idea: the Stingray Pipeline Company has proposed a pipeline system in the Gulf of Mexico of 300 miles in length, costing $150,000,000 [IPE-73]. Phase I of the Stingray project will cost $105,000,000 and will service an area off the coast of western Louisiana, extending approximately 125 miles into the Gulf and approximately 100 miles from the Texas-Louisiana state line to the east [OGJ-73-1]. The costs of pipeline to bring gas from the north slope of Alaska and Canada to the lower 48 states are even greater. A consortium of mid-western gas companies have submitted to the Federal Power Commission and the National Energy Board of Canada a plan to build a 2600 mile 48" pipeline, at an estimated cost of approximately $5.7 billion from Alaska to the southern Canada-U.S. border [OGJ-74-1]. Possible routes for this pipeline and other lines to bring gas from Alaska and the far north are shown in Figure D-2. An additional $3.1 billion will be required for transmission lines within the lower 48 states bringing the total to $8.8 billion. However, it may be that U.S. gas companies will not have to cover this entire cost. Canadian national policy developments may require that Canada retain financial control of the portion of the line within their borders: costs borne by Canada under such a financial arrangement would be more than $1 billion. The capital cost estimates here are only for actual transportation of gas. The gas industries are predicting changes in the source of gas, e.g., gasification; and hence their own capital cost projections are likely to be significantly different from the ones given here, even if the usage projections of the AGA agree with the scenario under consideration.

For comparison purposes, the projections of the three scenarios examined here are summarized in Table D-2 in addition to the projections of the American Gas Association, Table D-3. The capital requirements for the gas transportation industry under the scenarios are summarized in Table D-4. In the tables, Category I includes transmission, storage and distribution line facilities in the lower 48 states; in recent years this category has been averaging approximately $2.8 billion per year. In all three scenarios, this category becomes smaller toward the end of the century because gas

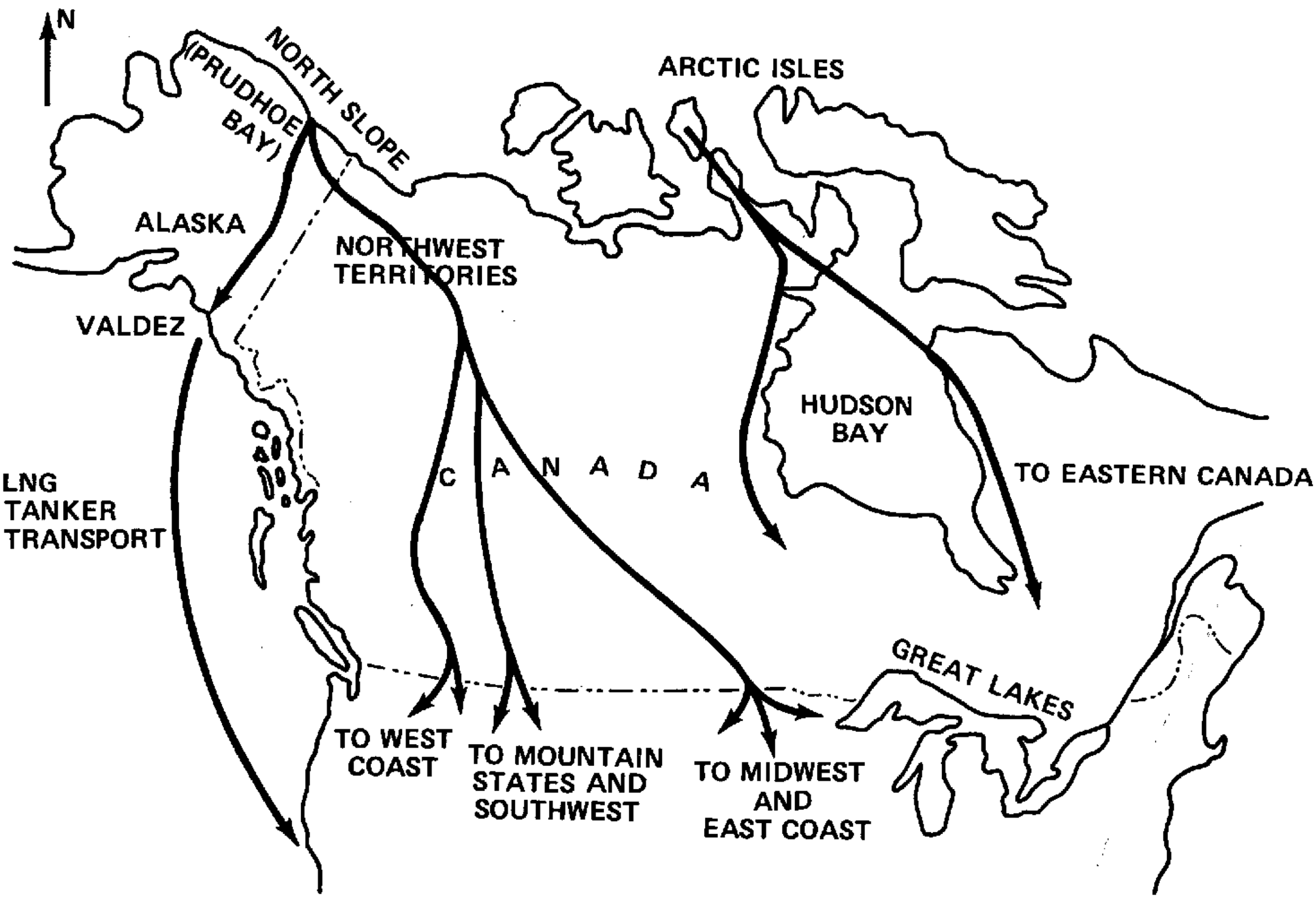


FIGURE D-2 POSSIBLE ROUTES OF GAS TRANSPORTATION FROM ALASKA AND NORTHERN CANADA

TABLE D-2 SCENARIO PROJECTIONS OF GAS USAGE
(10^{15} BTU/YEAR)

	1972	1975	1980	1985	1990	1995	2000
NEE Scenario							
Domestic	21	22	22	23	18	13	9
Imported	2	2	2	3	2	1	0
Synthetic	0	0	0	1.2	3.6	6	10
Total	23	24	24	27.2	23.6	20	19
FTF Base Scenario							
Domestic	21	--	23.2	26.6	27.5	28.5	28.5
Imported	2	--	5.4	5.5	5.6	5.1	3.9
Synthetic	0	--	0.0	0.0	0.0	0.0	0.0
Total	23		28.6	32.1	33.1	33.6	32.4
FTF Alternate Scenario							
Domestic	21	--	26.1	30.0	32.6	31.6	29.7
Imported	2	--	3.6	6.1	6.0	4.8	2.7
Synthetic	0	--	0.0	0.0	0.0	0.0	0.0
Total	23		29.7	36.1	38.6	36.4	32.4

TABLE D-3 GAS USE AND SOURCE PROJECTIONS (TCFY)

	AGA Projections				
	1972	1975	1980	1985	1990
Domestic Gas (Lower 48)[a]	22	20.5	20.5	23.9	25
Domestic Gas (Alaska)	0	0	1.0	1.0	1.0
Imp. (from Canada)	1	1.3	1.8	2.4	2.9
Imp. (by LNG tanker)	0	.2	1.7	2.7	3.1
	22.	22.	25.	30.	32.

a) Includes gasification of coal and onshore and offshore natural gas production.

TABLE D-4 GAS INDUSTRY TRANSMISSION, DISTRIBUTION, AND STORAGE CAPITAL REQUIREMENTS
(Figures are in $ Billion within 5-year period)

Category	1976-80	1981-85	1976-90	1991-95	1996-2000
			NEE Scenario		
I	8.0	8.0	4.0	3.5	3.0
II	5.0	5.0	5.6	0.	0.
III	4.5	4.5	4.5	0.	0.
Total	17.5	17.5	14.1	3.5	3.0
			FTF Base Scenario		
I	12.0	15.0	10.0	5.	3.
II	4.4	6.8	4.4	0.	0.
III	14.0	4.0	0.0	0.	0.
Total	30.4	25.8	14.4	5.0	3.0
			FTF Alternate Scenario		
I	15.	15.	15.	8.	5.
II	5.2	6.2	3.8	0.	0.
III	14.0	14.	0.	0.	0.
Total	34.2	35.2	18.8	8.0	5.0

usage levels off or decreases, and hence capital requirements are mainly for changes in the distribution system, i.e., to new homes or apartment buildings, with concurrent shut-down of lines to former users. Category II includes construction of lines from Alaska to lower 48 markets. In accordance with the resource projections in Appendix B-1, a second line, over and above present AGA projections, has been included. Capital costs in Category II include $7.8 billion for each of the two lines, using the assumption that $1 billion of Canadian capital will be used on each line, and also assuming that duplication costs will be equal to costs for the original lines.* Category III includes capital costs for LNG tankers, and liquefication, handling, and storage facilities. The capital costs in this category are based on AGA projections that approximately $18 billion will be required by 1985, to handle the importation annually of 2.7 trillion cubic feet [AGA-74]. Some of the costs to the gas industry, such as offshore gathering systems have been included in the oil transportation requirements, as discussed in Appendix D-3.

For purposes of comparison, the National Petroleum Council [NPC-72] has also performed several projections of capital requirements of the gas transportation industry. The NPC performs analyses for 4 different gas utilization scenarios ranging from high growth rates to zero growth rate; the projections are for the time period from 1971 to 1975. Figures developed in this present report give projections quite similar to the NPC projections, in those cases where the NPC scenarios for total gas utilization are similar to the scenarios of this report.

One additional comment needs to be made on the NEE path. Some of the synthetic gas, in this scenario, will likely be manufactured right at the coal mine, and then transmitted to load centers. Estimates for pipelines to transmit this synthetic gas are included in Appendix D-4.

Estimates of manpower and steel requirements for gas industry scenarios are made concurrently with oil requirements, and are in Appendix D-3.

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*As this report was going to press, new information was received, that as much as 300 trillion cubic feet of gas may be found in the Prudhoe Bay area of Alaska [McNeil-74]. Should this prove true, one might anticipate as many as 10 pipelines to Alaska by the end of the century. The capital projections given in Table D-4 would need to be reworked drastically (or more accurately, the three paths will likely be reconstructed.)

D-3 OIL AND OIL PRODUCTS TRANSPORTATION

The transportation of oil and oil products is an extremely complicated system. Transportation is performed in systems ranging in size from 2000 mile pipeline systems and 1000 foot long tankers, down to trucks and railroad cars. The work of this project has not attempted to analyze the requirements of the scenarios in terms of each segment of the entire system, but has instead decided to use the history of the oil industry. Table D-5 gives a history of oil industry capital expenditures; numbers in the table show percentages and trends that will be used in the analyses below.

First, there is one major problem in using Table D-5, and that is the area of tanker capital expenditures. A large segment of the tankers of the world are purchased by American oil industries but are not built in the U.S., nor do they fly the U.S. flag. Consequently, the figures in Table D-5 for U.S. tankers is less than the expenditure for tankers actually used in transporting oil to the U.S. (or for transporting oil within the U.S.--significant oil shipments proceed from one U.S. port to another, e.g., from Gulf Coast ports to east coast ports.) Figure D-3 is included to give an idea how the U.S. oil imports compare to world oil transportation. Probably about 10 percent of the world's tankers are required to bring oil to the U.S.

Note that pipeline capital expenditures in the U.S. in Table D-5 range from approximately 5 percent to 17 percent of the costs for production. As an average, the figure of 10 percent will be used in calculations. In Appendix B-1, estimates have been made of the exploration and development capital required by the oil and gas industry; the figures used for pipeline construction capital for oil products here is simply 10 percent of the resource capital figure.

The estimation of capital requirements for tankers, even as a percent calculation, is more complicated than for pipelines. In all the scenarios, the use of imported oil does not increase significantly from present levels, and is reduced toward the year 2000. It is certainly possible to argue that under these conditions the capital for tankers is zero. However, there is always the need for capital to replace tankers as they grow old, or to replace older vessels with more efficient supertankers. An attempt has been made to estimate these costs as follows. In 1972, the U.S. imported 10 quadrillion Btu of oil. In the same year, 10 percent of world capital expenditures on tankers was (from Table D-5) approximately $365 million. Assuming that this ratio of expenditures to energy imports holds in the future (and ignoring the time lag between capital expenditure for tankers and actual tanker utilization) then for each quad of energy imported to the U.S. in a given year, $36 million must be spent on tankers. However, this figure is probably too low, as indicated by the following calculation.

A second way to estimate the capital required to import energy by tankers may be obtained from a unit analysis. The estimated cost for a 400,000 ton DWT supertanker is $120 million [BUS. WK.-74-1]. This same tanker carries, per trip, approximately 17×10^{12} Btu energy equivalent. For a total importation of one Quad of energy (10^{15} Btu), 60 arrivals of these tankers is required. Assuming further that one tanker requires

TABLE D-5 DISTRIBUTION AND PRODUCTION CAPITAL EXPENDITURES
OF PETROLEUM INDUSTRIES
($ MILLION)

Year	Pipelines	Pipeline Percent Of Production	Tankers	Production	Tankers
1962	300	8	40	3850	840
1963	375	11	40	3525	900
1964	275	7	65	3800	1275
1965	225	6	40	3600	1175
1966	275	8	25	3600	1265
1967	360	10	40	3750	1215
1968	425	9	50	4675	1600
1969	300	7	100	4525	1950
1970	450	11	100	4110	2475
1971	550	17	125	3185	2750
1972	300	5	125	5740	3650

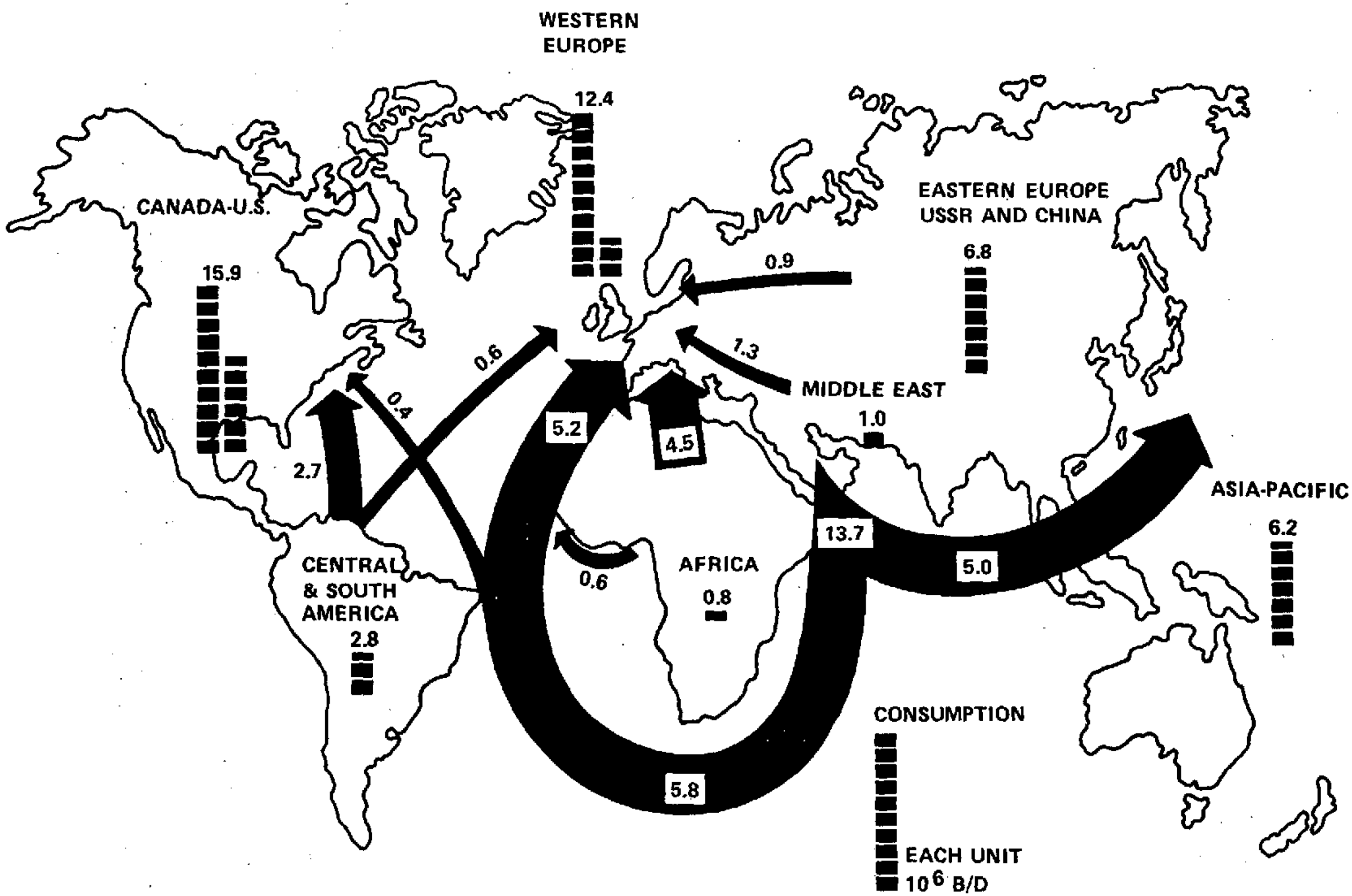


FIGURE D-3 1970 WORLD PETROLEUM CONSUMPTION AND MAJOR MOVEMENTS [Shell-73]

2 months for a complete round trip (in fact, trips to and from the mid-east via South Africa require 4 months, and round trips to Venezuela require about 1 month), and assuming that each ship has a 10 year life (probably too short), one such supertanker must be constructed each year for each quad of energy imported. This calculation implies that \$120 million must be spent per year per quad of imported energy. (The advantage of supertankers is seen from the fact that in 1971, there were 46,235 tanker arrivals in the U.S., bringing approximately the same 10 quads of energy [Clement-73]. In the calculations here, 600 supertanker arrivals would be sufficient.)

In the tables below, the figure of \$60 million capital expenditures per year per quad of imported oil energy will be used. This figure is approximately twice the gross investment capital calculation, and is half the unit investment calculation figure. As an example of the calculations, consider the 1976-80 NEE capital requirements. The NEE scenario projects that in 1980, the U.S. will import 12 Quadrillion BTU of oil energy. The figure of \$60 million per year per 10^{15} BTU means that in the 5 year time span from 1976 to 1980, the capital required will be:

$$\text{Capital required in 5-year period} = (12 \text{ QBtu}) \frac{(\$60 \text{ million})}{\text{QBtu - yr.}} (5 \text{ yr.}) = \$3.6 \text{ Billion.}$$

The calculations described above do not include the necessity or desireability for supertanker ports. Present projected costs for "superports" range from \$100 million to \$1 billion each. A total of \$1 billion has been included for superports only for the NEE path, since this is the only path of the three under study here which allows for significant oil imports after 1985.

There is one major capital cost not included in the description above, the trans-Alaska pipeline system (TAPS). The total cost of this system of \$4.5 billion includes pipeline and tanker facilities for shipping oil from Valdez, Alaska to west coast lower 48 ports. This cost has been included in the 1976-1980 time frame, even though some of the capital has already been spent. Total capital costs for all three scenarios are given in Table D-6.

Manpower Requirements

The manpower requirements for oil and gas transportation have been lumped together in this section because oil and gas use very similar transportation techniques: tankers and pipelines. Attempts have been made here to suggest both the construction and operating personnel requirements in addition to engineer requirements.

The best information on engineers in the gas and oil transportation industry comes from the National Petroleum Council. In 1967, the following numbers of engineers were employed in the United States.

TABLE D-6 CAPITAL REQUIREMENTS FOR OIL TRANSPORTATION

	1976-80	1981-85	1986-90	1991-95	1996-2000
NEE Scenario					
Tankers & Facilities	3.6	2.8	1.2	.9	.6
Pipelines in U.S.	1.5	1.7	1.9	2.0	2.1
Alaska Pipeline	4.5	0	0	0	0
Total	9.6	4.5	3.1	2.9	2.7
FTF Scenario					
Tankers & Facilities	3.0	.4	0	0	0
Pipelines in U.S.	1.7	2.0	2.3	2.4	2.3
Alaska Pipeline	4.5	0	0	0	0
Total	9.2	2.4	2.3	2.4	2.3
Tankers & Facilities	3.4	1.5	0	0	0
Pipelines in U.S.	1.5	1.6	1.6	1.5	1.3
Alaska Pipeline	4.5	0	0	0	0
Total	9.4	3.1	1.6	1.5	1.3

TABLE D-7 ENGINEERS IN OIL AND GAS TRANSPORTATION INDUSTRY, 1967 [NPC-69]

Oil Pipelines		
Crude Oil and Oil Products	808	
Support (design, etc.)	122	
	930	930
Gas Pipeliens		
Natural Gas Field	156	
Natural Gas Transmission	821	
Support (design, etc.)	1013	
	1990	1990
Marketing		
Oil and Gas Marketing	2603	
Support	305	
	2908	2908
Marine Transport		
Ocean Tankers (shore)	98	
Barges and Tugs	299	
Support	75	
	472	472
Grand Total		6300

The engineering manpower figures in Table D-7, above, are utilized for scaling purposes, in the final tabulations.

There is a second way to estimate engineers required in the gas and oil transportation industry. A source at Alyeska Pipeline Company (who preferred to remain anonymous) provided figures on engineering man-hours on the TAPS System. These figures provide the conclusion that approximately 230 engineers were required for the design phase of the pipeline, working for approximately 5 years. (These engineers were sufficient to cover all phases of the work, including the pipeline itself, pump-stations, necessary road construction, and the tanker terminal at Valdez.) In addition, perhaps 300 construction engineers will be required along the pipeline route, at the height of construction, when approximately 10,000-14,000 construction workers will be employed. (In the summer of 1974, about 100 construction engineers were employed, and 4,000 construction workers.) These figures can be extrapolated to obtain the engineering manpower requirements for other major pipeline construction efforts-- e.g., the trans-Canada gas pipelines, for which no estimates of manpower were obtained through direct sources.

A third method of estimating engineering manpower requirements is based on the capital requirements of major projects. On the TAPS System, approximately 1 percent of the total $4.5 billion cost was required for the design engineering effort; an figure of $20 per engineering man-hour gives approximate agreement with the above figure on the engineering man-years quoted for the TAPS System. However, the percentage of capital required for engineers will often be higher. One would expect that for LNG tankers, storage equipment, etc., for which the technology is not as well established as for pipes, the percent of capital for engineers will be higher. Further complication is provided by the fact that in some areas, like pipeline construction in Alaska, engineers will in the future request and receive significantly higher salaries, i.e., well above inflationary trends. The source at Alyeska stated that already there is a real shortage of engineers, and that engineers are beginning to search actively for the highest paying positions. Consequently the percentage of capital required for engineering salaries may well go up, even though such increases do not reflect larger requirements for engineering manpower. The figures used below reflect usage of the 1 percent of capital and $20 per engineer-manhour calculations, except in the case of LNG tankers, and facilities, for which 2 percent of capital and $20 per engineer man hour have been used. The final values for engineers given in Table D-8 are estimates using all three of the ideas given above.

Construction manpower is another problem. In the pipeline industry, it is commonly accepted that the total manpower requirements, for both operation and construction, are dropping. The use of computers to actuate automatic valves, and other technological advances, is steadily reducing the operational personnel required for pipeline systems. In addition, the advent of plastic pipes for gas and oil feeder and distribution lines is reducing the manpower required for installation. Pipes made of plastic

TABLE D-8 ENGINEER POPULATIONS REQUIRED FOR THE SCENARIOS

	1980	1985	1990	1995	2000
			NEE Scenario		
Gas Pipelines	2600	3000	2600	2400	2400
Oil & Products Pipelines	1100	1100	1100	1100	1100
LNG Tankers & Facilities	490	490	0	0	0
Marine Transport (Oil)	600	600	500	400	400
Marketing	5000	5000	5000	5000	5000
	9790	10190	9200	8900	8900
			FTF Base		
Gas Pipelines	3000	4000	6000	4000	3000
Oil & Products Pipelines	1100	1000	1100	1100	1500
LNG Tankers & Facilities	2800	800	--	--	--
Marine Transport (Oil)	600	400	400	400	400
Marketing	5000	4000	5000	5000	5000
	12500	10200	12500	10500	9900
			FTF Alternate		
Gas Pipelines	4000	6000	8000	5000	3000
Oil & Oil Products Pipelines	1300	1500	1500	1500	1500
LNG Tankers & Facilities	2800	2800	--	--	--
Marine Transport (Oil)	600	400	400	400	500
Marketing	6000	6000	6000	5500	5000
	14700	16700	15900	12400	10000

are much lighter, and crews of perhaps 10 men, for feeder line installation after trenches have been dug, are being reduced to as low as 3 men. In similar fashion, the time required for gas distribution line installation, e.g., to residential homes, is shorter, with plastic gas lines, and consequently fewer workers may be needed. (However, use of plastic lines to homes may not meet safety requirements. In at least one recorded case [DP-73], a plastic gas line to a home cracked when construction equipment subsequently moved over the buried line, leading to an explosion in a home and death for a resident.)

The construction manpower requirements for U.S. tankers are very hard to estimate, for the simple reason that the United States is not the primary world source of tankers. Consequently, there is no guarnatee that the tankers required will be built in U.S. shipyards. The present tanker construction manpower of 10,000 in the U.S. is probably sufficient for the needs of all three scenarios. (The number 10,000 was found as follows: there were in 1971,104,700 ship production workers in U.S. shipyards [DOC-73-1]. Of the major ship construction done, half was commercial and half was military. Of the commercial half, about one-fifth was in the construction of tankers. These numbers taken together give 10,000 tanker construction workers.)

In fact, since the scenarios show a decrease in oil and gas imports after 1985, the manpower requirements for both construction and operation of tankers will show marked decreases.

In 1970, the total gas company employment was 164,000, according to Department of Labor statistics [DOL-72]. The AGA provides the figure of 211,700 employees in 1970 [AGA-72-1]. The reasons for the differences in these figures is unclear. The Department of Labor also gives 140,000 as the employees in "non-supervisory" positions. For the purposes of this report, we have assumed that about one-sixth of the DOL number of workers, or about 20,000 work as distribution construction line workers, and that 10,000 operate and maintain already constructed gas distribution and transmission lines.

Major transmission line construction is, as mentioned above, performed by contract construction firms, not by the gas companies themselves. To perform this work, there are at present 5,000 members of the Pipefitters Union Local 798 of Tulsa, Oklahoma [Hendricks-1974], whose workers perform about 75-80 percent of all welding and pipefitting work done on major pipelines in the U.S., including Alaska. In addition to these men, there are at present about 20,000-25,000 other pipeline workers [McNeil-74], the support workers for the welders. It should be pointed out that this manpower pool is not at present fully utilized, since various constraints including shortages of pipe are holding back pipeline construction. Last year there were only about 4,000 miles of major pipeline constructed, of 30 inch diameter and up, compared to 18,000 miles in 1968. Many workers available for pipeline construction are presently at work in other areas.

The manpower required to operate a tanker is approximately 20 men; this figure is more or less the same regardless of tanker size. There were in 1972, 238 tankers of U.S. registry [CMB-73], which required,

therefore, approximately 5,000 American merchant marine personnel. We shall assume that any other tankers required to bring oil to the U.S. will have foreign crews, even though such ships may have been built with American capital.

The various suggestions above permit the tabulations in Table D-9.

Steel Requirements

As in the manpower requirements, both the oil and gas steel transportation requirements will be handled in this section. However, steel requirements estimates are much easier to make. The weight of steel pipes as a function of pipe size is readily available (e.g. [Mech. Eng. Hdbk-58]). In addition, the cargo weight capacity of tankers is given directly when the tanker size is specified. For calculations here, a 100,000 DWT tanker requires approximately 15,000 tons of steel. As before, however, complications arise when projections are made as to where the steel will come from. Foreign built tankers use, naturally, foreign steel. And pipeline used in the U.S. is also constructed in foreign countries. For example, the steel in the Alaska pipeline was constructed in Japan; at the time of purchase, U.S. steel manufacturers did not produce steel pipe of the required 48" diameter.

For purposes of this calculation, it is assumed that all future pipe will be manufactured in the U.S., that all LNG tankers will be built in the U.S., and that one fourth of the oil tankers will be built in the U.S. Total steel estimates for all three scenarios are shown in Table D-10.

TABLE D-9 CONSTRUCTION AND OPERATION PERSONNEL, FOR OIL AND GAS TRANSPORTATION

	1980	1985	1990	1995	2000
			NEE Scenario		
Gas line operational	30,000	30,000	30,000	30,000	30,000
Oil line operational	10,000	10,000	10,000	10,000	10,000
Pipeline construction	30,000	30,000	30,000	30,000	30,000
Tanker construction	10,000	7,500	3,500	3,000	2,000
Tanker operation	6,000	3,000	2,000	1,500	1,000
	86,000	80,500	75,500	77,500	73,000
			FTF Base Scenario		
Gas line operational	30,000	30,000	30,000	30,000	30,000
Oil line operational	10,000	10,000	10,000	10,000	10,000
Pipeline construction	30,000	32,000	34,000	34,000	34,000
Tanker construction	15,000	10,000	3,000	3,000	3,000
Tanker operation	5,000	2,000	2,000	2,000	2,000
	90,000	84,000	79,000	79,000	79,000
			FTF Alternate Scenario		
Gas line operational	30,000	30,000	30,000	30,000	30,000
Oil line operational	10,000	10,000	10,000	10,000	10,000
Pipeline construction	40,000	45,000	45,000	35,000	30,000
Tanker construction	11,000	5,000	3,000	2,000	1,000
Tanker operation	6,000	5,500	3,000	2,000	1,000
	97,000	95,500	91,000	79,000	72,000

TABLE D-10 STEEL REQUIREMENTS OF OIL AND GAS TRANSPORTATION (10^6 tons)

	1976-80	1981-85	1986-90	1991-95	1996-2000
			NEE Scenario		
Pipeline	4.6×10^6	4.6×10^6	3.6×10^6	2×10^6	2×10^6
Tankers, LNG	2.4×10^6	2.4×10^6	2.4×10^6	0.0	0.0
Tankers, Oil	0.5×10^6	0.3×10^6	0.3×10^6	$.2 \times 10^6$	$.2 \times 10^6$
Total	7.5×10^6	7.3×10^6	7.3×10^6	2.2×10^6	2.2×10^6
			FTF Scenario		
Pipelines	6.6×10^6	6.1×10^6	3.5×10^6	2.5×10^6	2×10^6
Tankers, LNG	6.0×10^6	2.0×10^6	0	0	0
Tankers, Oil	0.5×10^6	0.2×10^6	0	0	0
Total	13.1×10^6	8.3×10^6	3.5×10^6	2.5×10^6	2×10^6
			Alternate FTF Scenario		
Pipelines	7.6×10^6	6.1×10^6	6.1×10^6	3×10^6	2.5×10^6
Tankers, LNG	6×10^6	6×10^6	0	0	0
Tankers, Oil	0.5×10^6	0.3×10^6	0	0	0
Total	14.1×10^6	12.3×10^6	6.1×10^6	3×10^6	2.5×10^6

D-4 COAL TRANSPORTATION

The present transportation picture with regard to coal as well as some of the requirements for future expansion of coal transportation are examined in the following sections.

D-4-1 PRESENT COAL TRANSPORTATION SITUATION.

After mining and local cleaning, coal is shipped to customers via:

rail	belt conveyor
barge, ship	truck
multi-mode	slurry pipeline

Coal constitutes the railroad's single most important commodity class in terms of carloads and tonnage. See Table D-11.

TABLE D-11 COAL MOVEMENTS BY CLASS I RAILROADS [DOC-73][DOC-72]

Year	Million Tons	% of Total	Million Cars	% of Total	Tons Per Car
1971	360.6	26	4.6	18	78
1970	404.6	27	5.3	20	76

Unit trains have generated considerable publicity as a means of coal transportation. A unit train consists typically of a set of privately owned hopper cars pulled by a team of railroad-owned locomotives dedicated to unit train service. Operation is usually on a regular schedule between a single origin and single destination. The train is not broken down and it can be assembled from the loads of several small coal producers; usually however, only one producer is served. A representative unit train movement is a 500 car train hauling 48,000 tons of coal using six diesel locomotives (21,600 HP combined). Three locomotives are at the head and three "slave" units are further back in the train but controlled from the head units. It is estimated that from one-third to one-half of coal shipments by rail are by unit train [NPC-73].

The governing tariffs for unit trains not only specify the origin and termination, but also the minimum tonnage (usually 7000 tons per train) and allowable times for loading and unloading.

As reported by the National Power Survey, rail transportation costs for coal ranged from 0.7 cents per million BTU to 8.3 cents per million BTU per 100 miles. Unit train costs per million BTU per 100 miles were roughly

one-half the costs associated with the regular rate tariffs for coal. [AUI-72].

Many utilities planning new coal-fired electrical generating stations are using rates around 5 mills per ton per mile [MIT-74]; using 17 million BTU per ton of western coal this figure equates to 3 cents per million BTU per 100 miles and with 25 million BTU per ton coal the figure is 2 cents per million BTU per 100 miles.

Waterborne movement of coal takes place in several ways:

on inland rivers and canals

on the Great Lakes

along the coast

local movements within harbors and ports.

Movement on inland waterways is by far the most important, the coal tonnage moved being more than three times that shipped on the Great Lakes and ten times the coal tonnage moved along the coast. Accordingly, the remainder of this discussion will focus on coal movement by barge. The reader is referred to the following references for greater detail on all movements of coal: [NPC-73], [Kearney-74],

Barge movement of coal represents the third most important tonnage movement on the inland waterways, with about one fifth of the total tonnage. (Petroleum and petroleum products are the most important.)

A representative barge configuration would be nine barges, three abreast, holding 21,000 tons of coal and being pushed by a 3000 hp tow-boat. Movements up to 50,000 tons are possible. Channel width and other navigational considerations, rather than barge capacity and towboat power, are the constraints on maximum tonnage movements. Maximum size of a single barge is about 3000 tons and maximum towboat horsepower around 6-8000 hp.

A river towboat can move 8 tons/hp as compared with an average 1 ton/hp hauled by a railroad locomotive. This fact, of course, fosters the lower unit costs for barge movement--the per ton-mile savings by using barge instead of rail is anywhere from 50 to 80 percent.

A problem in determining what fraction of coal moves by rail vs. what fraction moves by water is that some coal shipments use both modes; e.g., coal could be moved from mine to a river point by rail and loaded onto barges for shipping to a river-sited power plant. Rail-barge-rail sequences are not uncommon. A multi-mode movement is thus counted twice (or three times) in transportation statistics. Using 1969 data the following split is estimated for all-rail/all-water/rail & water: 60/10/10, where the numbers represent percentages of total U.S. coal output [NPC-73].

Use of belt conveyors to move coal is confined to "over-the-fence" situations, such as mine-mouth power generating plants.

Slurry pipeline movements are not currently a major form of coal transportation. One of the primary motives behind their suggested use has been to induce railroads to offer lower rates for specific point-to-point movements. This is confirmed by figures reported in the 1970 National Power Survey which indicate coal slurry pipeline movement costs around or just below comparable unit train costs [AUI-72]. A resurgence in the advocacy of coal slurry pipelines has occurred with regard to tapping the western coal reserves [NAE-74]; [BUS. WK.-74-2]; [OGJ-73-4]. Lines of 1000 miles in length, moving 25 million tons of coal per year are being considered.

D-4-2 UNIT REQUIREMENTS

The determination of distribution requirements per some measure of incremental measure of energy capacity is difficult because the "where" of the capacity addition, i.e., the locations of supply and demand, will determine whether entirely new additional distribution facilities are needed or whether existing facilities can be used. This condition hampers the micro- or "build-up" approach to estimating total requirements. Hence a macro- or broad value ratio approach will often be employed in the subsequent section.

Unit capital requirements for coal transportation by rail are estimated to be $20 million for every additional 1 million tons to be moved by rail, including rail plus barge tonnages, i.e., 60% + 10% = 70% of coal output. The figure of $20 million was arrived at as follows: outlays for new rail plant and equipment for the 1970-80 time period were estimated to be between $5 and $6 billion [NPC-73]. The anticipated rail coal traffic increase inducing this investment is figured to be 70 percent of the anticipated coal production increase over the ten-year period of 380 million tons. The above yields $5.5 billion/266 million tons of approximately $20 million per 1 million tons of coal shipped by rail.

The investment required for barge movement of additional coal output is computed in a similar fashion. For the five-year period 1971-1975 an estimated $500 million are needed [NPC-73]. With coal responsible for one-fifth of the total barge tonnage moved presumably one-fifth of the $500 million would go into coal barges and associated towboats. Note that investment in new locks and channel widening and deepening, which the industry feels the government must make, is <u>not</u> included. The expected inland waterways coal tonnage increase bringing about the $100 million investment is 18 million, per interpolation of data in Table K-1 of [NPC-73]. This yields a unit capital requirement of $5.5 million for every 1 million in coal tonnage moved by barge.

The cost of one 1000 mile coal-slurry pipeline is estimated at $600 million, as obtained by extrapolating and adjusting figures for a 500-mile line reported in [Hottel-71]. Conversations with a pipeline engineer of a firm wishing to remain unidentified put the cost of such a line between $500 and $750 million.

Unit steel requirements for coal transportation expansion are

developed in a two-step process. First the number of 100-ton capacity hopper cars required per million tons of rail coal movement is estimated. This ratio is used to determine the number of cars any given production increase requires. Noting that each 100-ton hopper car weighs 30 tons (practically all of which is steel) enables the calculation of steel requirements [RPI-74]. The ratio of cars per million tons is developed from data in the National Academy of Engineering study NAE-74 . There 150,000 hopper cars were estimated to be needed to support a 400 million ton increase in coal shipments via rail, i.e., 375 cars per million tons.

The unit steel requirements for railroad rails runs 230 tons/mile. using 130 pound-per-yard rail [RPI-74].

Locomotives weigh 200 tons each, just about all of which is steel.

The unit steel requirements for barges are determined as follows: total barge cargo is expected to increase some 464 million tons by the year 2000, requiring additions to barge capacity of 14 million tons [Kearney-74]. That is, a 33 million ton cargo increase requires 1 million additional tons of barge capacity. At 1500 tons per typical coal barge, 1 million tons capacity is equivalent to 670 1500-ton barges. One million tons of cargo increase, therefore, requires 20 barges (670 barges/ 33 million tons). Each 1500 ton barge weighs 285 tons [Dravo-74].

The unit steel requirements for towboats and lock construction as well as all concrete requirements for coal transportation system construction have not been analysed here.

A steel requirement arises in the use of coal slurry pipelines. The nominal weight of a 38-inch diameter, 3/8-inch average wall thickness pipeline is 430 tons per mile.

Pipelines for coal slurry have another material requirement of considerable importance, especially when one notes these lines are being suggested for use in the western coal lands; that requirement is water. Based on data in [OGJ-73-4] a coal slurry line handling 25 million tons of coal per year requires 5 billion gallons of water per year.

Determining the manpower requirements for coal transportation is difficult because unlike petroleum transportation and electrical transmission the transport facilities for coal (excepting the slurry line) are used to move other commodities as well. An allocation of the total manpower in rail and barge transport is thus needed. Such an allocation was not uncovered and so manpower estimates are not made here.

Tables D-12 through D-15 summarize the above material and provide additional unit requirement values for general reference purposes.

D-4-3 PATH REQUIREMENTS

To determine the materials and money requirements of coal transportation

TABLE D-12 SUMMARY OF UNIT CAPITAL REQUIREMENTS

Element	Value
Rail Plant & Equipment Investment per million tons of coal moved	\$ 20 million
Inland Waterways Equipment Investment per million tons of coal moved	\$5.5 million
Cost of one 1000-mile 25 MTPY coal slurry pipeline	\$600 million

TABLE D-13 SUMMARY OF UNIT EQUIPMENT REQUIREMENTS

Element	Value
Number of 100-Ton Hopper Cars per million tons of coal moved	375
Number of 1500-Ton Hopper Barges per million tons of coal moved	20

TABLE D-14 SUMMARY OF UNIT MATERIALS REQUIREMENTS

Element	Value
Tons of Steel Per 100-Ton Hopper Car	30
Tons of Steel Per 1500-Ton Hopper Barge	285
Tons of Steel Per Mile of New Rail Line	230
Tons of Steel Per 3000 hp Locomotive	200
Tons of Steel Per Mile of a 25 MTPY Coal Slurry Pipeline	430
Gallons of Water Per Year for a 25 MTPY Coal Slurry Pipeline	5×10^9

TABLE D-15 SUMMARY OF UNIT PRICE REQUIREMENTS

Element	Value ('72-'73 $)	Reference
Cost of a 100-Ton Hopper Car	$ 15,600	[AAR-74]
Cost of a 3000 hp Locomotive	$350,000	[AAR-74]
Cost Per Mile of a New Rail Line Over Smooth Terrain	$500,000	[WSJ-74]
Cost of a 3000 hp Towboat	$750,000	[Kearney-74]
Cost of Dry Cargo Barge (Approx. 1100 Tons)	$130,000	[Kearney-74]

under the three situations NEE, FTFB, AFTF, the coal production requirements of each must be detailed and the approaches to coal transportation in each situation delineated. These are presented in the accompanying tables. Specifically, Tables D-16 through D-19 present the production requirements for coal in the three scenarios and in the forms of its use. Note that synthetic fuels from coal appear in the NEE scenario and the FTFB, but not in the AFTF example. In the NEE case, Table D-17 indicates how the synthetic fuels might be produced.

Table D-20 contains the coal transportation approaches assumed for the purposes of this analysis. The reader is directed to note these assumptions.

The detailing of the production requirements and the transportation approaches now permits the determination of the modal requirements, i.e., how much coal is shipped by what mode of transportation; see Tables D-21 through D-23.

With the tonnages of coal now broken down by mode, the determination of capital and materials requirements for each path can be made using the appropriate unit requirements figures from the previous section. Tables D-24 through D-26 contain the capital requirements; Table D-27 presents coal slurry pipeline water needs; Tables D-28 through D-30 display the steel requirements.

The purpose of this section has been to present estimates of re-requirements of the paths; the estimates have omitted some requirements, as noted above, and need refinement.

TABLE D-16 COAL REQUIREMENTS BREAKDOWN

NEE PATH

Year	COAL-DIRECT Quads	COAL-DIRECT MM Tons	COAL-GAS[a] Quads	COAL-GAS[a] MM Tons	COAL-LIQUID[a] Quads	COAL-LIQUID[a] MM Tons	TOTAL Quads	TOTAL MM Tons
1975	17.0	680					17.0	680
1976	18.5	740					18.5	740
7	20.5	820					20.5	820
8	22.0	880					22.0	880
9	23.5	940					23.5	940
1980	25.0	1000					25.0	1000
1981	27.0	1080	.4	16			27.4	1096
2	28.0	1120	.8	32			28.8	1152
3	29.5	1180	1.2	48			30.7	1228
4	31.0	1240	1.6	64			32.6	1304
1985	32.0	1280	2.0	80			34.0	1360
1986	32.5	1300	3.0	120	.8	32	36.3	1452
7	33.0	1320	3.6	144	1.6	64	38.2	1528
8	33.5	1340	4.0	160	2.4	96	39.9	1596
9	34.0	1360	5.0	200	3.2	128	42.2	1688
1990	34.0	1360	6.0	240	4.0	160	44.0	1760
1991	34.5	1380	6.8	272	4.8	192	46.1	1844
2	35.0	1400	7.6	304	5.6	224	48.3	1932
3	35.0	1400	8.4	336	6.4	256	49.8	1992
4	35.5	1420	9.2	368	7.2	288	51.9	2076
1995	36.0	1440	10.0	400	8.0	320	54.0	2160
1996	36.5	1460	10.8	432	9.6	384	56.9	2276
7	37.0	1480	11.6	464	10.4	416	59.0	2360
8	37.5	1500	11.8	472	11.2	448	60.5	2420
9	38.5	1540	12.4	496	12.0	480	62.9	2516
2000	39.0	1560	14.0	560	12.8	512	65.8	2632

[a]Requirements expressed in pre-conversion amounts and are derived from Table D-18.

TABLE D-17 ASSUMED PLANT MIX FOR DETERMINING TRANSPORTATION NEEDS

FOR COAL CONVERTED TO GAS AND LIQUID[c]

NEE PATH

Period	QUADS REQ. Gas	QUADS REQ. Liq.	SNG PLANTS No.	SNG PLANTS GQ	COG PLANTS No.	COG PLANTS GQ	COG PLANTS LQ
1981	.4		2	.4			
2	.8		4	.8			
3	1.2		6	1.2			
4	1.6		8	1.6			
1985	2.0		10	2.0			
1986	3.0	.8	14	2.8	2	.2	.8
7	3.6	1.6	16	3.2	4	.4	1.6
8	4.0	2.4	17	3.4	6	.6	2.4
9	5.0	3.2	21	4.2	8	.8	3.2
1990	6.0	4.0	25	5.0	10	1.0	4.0
1991	6.8	4.8	28	5.6	12	1.2	4.8
2	7.6	5.6	31	6.2	14	1.4	5.6
3	8.4	6.4	34	6.2	14	1.4	6.4
4	9.2	7.2	37	7.4	18	1.8	7.2
1995	10.0	8.0	40	8.0	20	2.0	8.0
1996	10.8	9.6	42	8.4	24	2.4	9.6
7	11.6	10.4	45	9.0	26	2.6	10.4
8	11.8	11.2	48	9.6	28	2.8	11.2
9	12.4	12.0	51	10.2	30	3.0	12.0
2000	14.0	12.8	54	10.8	32	3.2	12.8

a) GQ= Quads of pre-conversion coal to produce gas

b) LQ= Quads of pre-conversion coal to produce liquid

c) Pre-conversion coal requirements (annual) for "typical":
SNG Plant .2 Quad to get coal gas
COG Plant .4 Quad to get coal liquids,
and .1 Quad to get coal gas

TABLE D-18 SOLID COAL REQUIREMENTS

NEE PATH

Year	COAL-DIRECT Quads	COAL-COG[a] Quads	TOTAL SOLID COAL Q	TOTAL SOLID COAL MM Tons
1975	17.0		17.0	680
1976	18.5		18.5	740
7	20.5		20.5	820
8	22.0		22.0	880
9	23.5		23.5	940
1980	25.0		25.0	1000
1981	27.0		27.0	1080
2	28.0		28.0	1120
3	29.5		29.5	1180
4	31.0		31.0	1240
1985	32.0		32.0	1280
1986	32.5	1.0	33.5	1340
7	33.0	2.0	35.0	1400
8	33.5	3.0	36.5	1460
9	34.0	4.0	38.0	1520
1990	34.0	5.0	39.0	1560
1991	34.5	6.0	40.5	1620
2	35.0	7.0	42.5	1700
3	35.0	8.0	43.0	1740
4	35.5	9.0	44.5	1780
1995	36.0	10.0	46.0	1840
1996	36.5	12.0	48.5	1940
7	37.0	13.0	50.0	2000
8	37.5	14.0	51.5	2060
9	38.5	15.0	53.5	2140
2000	39.0	16.0	55.0	2200

a)Derived from Table D-17

TABLE D-19 COAL REQUIREMENTS BREAKDOWN

FTF PATHS

	AFTF		FTFB					
	Coal-Solid		Coal-Direct		Coal-Synth		Coal-Solid	
Year	Quads	MM Tons	Quads	MM Tons	Quads	MM Tons	Quads	MM Tons
1975	13.2	528	12.5	500			12.5	500
1976	14.0	560	13.0	520			13.0	520
7	14.8	592	13.5	540			13.5	540
8	15.6	624	14.0	560			14.0	560
9	16.4	656	14.6	584			14.6	584
1980	17.2	688	15.2	608	1.0	40	16.2	648
1981	18.0	720	15.8	632	1.0	40	16.8	672
2	18.8	752	16.4	656	1.5	60	17.9	716
3	19.6	784	17.0	680	1.5	60	18.5	740
4	20.4	816	17.8	712	1.5	60	19.3	772
1985	21.2	848	18.4	736	2.0	80	20.4	816
1986	21.8	872	18.8	752	2.0	80	20.8	832
7	22.4	896	19.2	768	2.5	100	21.7	868
8	23.0	920	19.6	784	2.5	100	22.1	884
9	23.5	940	19.8	792	3.0	120	22.8	912
1990	24.0	960	20.0	800	3.0	120	23.0	920
1991	24.2	968	20.4	816	3.5	140	23.9	956
2	24.4	976	20.8	832	3.5	140	24.3	972
3	24.6	984	21.3	852	3.5	140	24.8	992
4	24.7	988	21.8	872	4.0	160	25.8	1032
1995	24.8	992	22.3	892	4.5	180	26.8	1072
1996	24.8	992	22.8	912	4.5	180	27.3	1092
7	24.8	992	23.3	932	5.0	200	28.3	1132
8	24.8	992	23.8	952	5.0	200	28.8	1152
9	24.8	992	24.3	972	5.5	220	29.8	1192
2000	24.8	992	24.8	992	6.0	240	30.8	1232

TABLE D-20 APPROACHES TO COAL TRANSPORTATION

NEE SCENARIO

Expansion of rail and barge systems to handle solid coal.

COG plants located near load centers to exploit existing gas and petroleum product pipeline networks and markets.

SNG plants located at mine; gas pipelines used to move SNG to load centers and to tap into existing NG transmission and distribution networks. After 1985 NG supplies exhausted, freeing lines for SNG movement.

Use of coal slurry pipelines to move western coal; in addition, rail barge systems.

FTFB SCENARIO

Expansion of rail and barge systems to handle solid coal.

Synthetic fuels from coal produced at plants near existing pipeline networks and markets (e.g., petro-chemical plants).

One long-distance coal slurry pipeline per decade.

AFTF SCENARIO

Expansion of rail-barge systems (not as rapidly as in prior two cases).

One long-distance coal slurry pipeline per decade.

TABLE D-21 MODAL REQUIREMENTS

NEE PATH

1976-1980

Solid coal output increase is 1000 - 680 =320 MM Tons.[a]

Via coal slurry pipeline, 50 MM Tons.

Via rail-barge systems, 80% of 270 = 220 MM Tons.[b]

1981-1985

Via gas pipeline, 2 Quads (SNG).

Solid coal output increase is 1280 - 1000 = 280 MM Tons.

Via coal slurry pipeline, 50 MM Tons.

Via rail-barge systems, 80% 230 = 180 MM Tons.

1986-1990

Via gas pipeline, 5 - 2 = 3 Quads (SNG), increase.

Solid coal output increase is 1560 - 1280 = 280 MM Tons

Via coal slurry pipeline, 50 MM Tons.

Via rail-barge systems, 80% of 230 = 180 MM Tons.

1991-1995

Via gas pipeline, 8 - 5 = 3 Quads (SNG), increase.

Solid coal output increase is 1840 - 1560 = 280.

Via coal slurry pipeline, 50 MM Tons.

Via rail-barge systems, 80% of 230 = 180 MM Tons.

TABLE D-21 (cont.) MODAL REQUIREMENTS

NEE PATH

1996-2000

Via gas pipeline, 10.8 - 8.0 = 3 Quads (SNG), increase.

Solid coal output increase is 2200 - 1840 = 360 MM Tons.

Via coal slurry pipeline, 50MM Tons.

Via rail-barge systems, 80% of 310 = 250 MM Tons.

a) Solid coal output from Table D-18

b) Remainder used in mine-mouth operation

Note: 80% rail-barge share is 60% all-rail, 10% all-barge, and 10% rail-barge.

TABLE D-22 MODAL REQUIREMENTS
FTFB PATH

1976-1980

Solid coal output increase is : 648 - 500 = 148 MM Tons.[a]

Via coal-slurry pipeline, 25 MM Tons.

Via rail-barge systems, 80% of 123 = MM Tons.[b]

1981-1985

Solid coal output increase is: 816 - 648 = 168 MM Tons.

Via rail-barge systems, 80% of 168 = 130 MM Tons.

1986-1990

Solid coal output increase is: 920 - 816 = 104 MM Tons.

Via rail-barge systems, 80% of 152 = 120 MM Tons.

1996-2000

Solid coal output increase is: 1232-1072 = 160 MM Tons.

Via rail-barge systems, 80% of 160 = 130 MM Tons.

a) Solid coal output from Table D-19.

b) Remainder used in mine-mouth operations.

Note: 80% rail-barge share is 60% all rail, 10% all-barge, and 10% rail-barge.

TABLE D-23 MODAL REQUIREMENTS

AFTF PATH

1976-1980

Solid coal output increase is: 688-528 = 160 MM Tons[a].

Via coal-slurry pipeline, 25 MM Tons.

Via rail-barge systems, 80% of 135 = 110 MM Tons.[b]

1981-1985

Solid coal output increa0e 6s: 848 - 688 = 160 MM Tons.

Via rail-barge systems, 80% of 160 = 130 MM Tons.

1986-1990

Solid coal output increase is: 960 - 848 = 112 MM Tons.

Via coal-slurry pipeline, 25 MM Tons.

Via rail-barge systems, 80% of 87 = 70 MM Tons.

1991-1995

Solid coal output increase is: 992 - 960 = 32 MM Tons.

Via rail-barge systems, 80% of 32 = 30 MM Tons.

1996-2000

Solid coal output increase is Zero.

a) Solid Coal output from Table D-19

b) Remainder used in mine-mouth opterations

Note: 80% rail-barge share is 60% all-rail, 10% all-barge, and 10% rail-barge.

TABLE D-24 CAPITAL REQUIREMENTS

NEE PATH

1976-1980		
Two 25 MTPY, 1000-mile coal-slurry pipelines @ $600 million		$1200 million
Expansion of rail system 70% (220 MM Tons) @ $20 million		3080
Expansion of barge system 20% (220 MM Tons) @ $5.5 million		240
	Total	$4520 million
1981-1985		
Two 2.5 BCPD, 1000-mile gas pipelines @ $500 million		$1000 million
Two 25 MTPY, 1000-mile coal-slurry pipelines @ $600 million		1200
Expansion of rail system 70% (180 MM Tons) @ $20 million		2520
Expansion of barge system 20% (180 MM Tons) @ $5.5 million		200
	Total	$4920 million
1986-1990		
Three 2.5 BCPD, 1000-mile gas pipelines @ $500 million		$1500 million
Two 25 MTPY, 1000-mile coal-slurry pipelines @ $600 million		1200
Expansion of rail system 70% (180 MM Tons) @ $20 million		2520
Expansion of barge system 20% (180 MM Tons) @ $5.5 million		200
	Total	$5420 million

TABLE D-24 (cont.) CAPITAL REQUIREMENTS

NEE PATH

1991-1995	
(Same calculations as 1986-1990).	$5420 million
1996-2000	
Three 2.5 BCPD, 1000-mile gas pipelines @ $500 million	$1500 million
Two 25 MTPY, 1000-mile coal-slurry pipelines @ $600 million	1200
Expansion of rail system 70% (250 MM Tons) @ $20 million	3500
Expansion of barge system 20% (250 MM Tons) @ $5.5 million	280
Total	$5800 million
1976-2000 NEE TOTAL	$25760 million

Note: 70% rail share is 60% all-rail
plus 10% rail-barge
20% barge share is 10% all-barge
plus 10% rail-barge

Tonnages per Table D-21

TABLE D-25 CAPITAL REQUIREMENTS

FTFB PATH

1976-1980		
One 25 MTPY, 1000-mile coal slurry pipeline @ $600 million		$ 600 million
Expansion of rail system 70% (100 MM Tons) @ $20 million		1400
Expansion of barge system 20% (100 MM Tons) @ $5.5 million		110
	Total	$2110 million
1981-1985		
Expansion of rail system 70% (130 MM Tons) @ $20 million		$1820 million
Expansion of barge system 20% (130 MM Tons) @ $5.5 million		140
	Total	$1960 million
1986-1990		
One 25 MTPY, 1000-mile coal slurry pipeline @ $600 million		$ 600 million
Expansion of rail system 70% (70 MM Tons) @ $20 million		980
Expansion of barge system 20% (70 MM Tons) @ $5.5 million		80
	Total	$1660 million

TABLE D-25 (cont.) CAPITAL REQUIREMENTS

FTFB PATH

1991-1995			
	Expansion of rail system 70% (120 MM Tons) @ $20 million		$1680 million
	Expansion of barge system 20% (120 MM Tons) @ $5.5 million		130
		Total	$1810 million
1996-2000			
	Expansion of rail system 70% (130 MM Tons) @ $20 million		$1820 million
	Expansion of barge system 20% (130 MM Tons) @ $5.5 million		140
		Total	$1960 million
		1976-2000 FTFB TOTAL	$9500 million

Note: 70% rail share is 60% all-rail
plus 10% rail barge
60% barge share is 10% all-barge
plus 10% rail-barge

Tonnages per Table D-22

TABLE D-26 CAPITAL REQUIREMENTS

AFTF PATH

1976-1980

One 25 MTPY, 100-mile coal-slurry pipeline @ $600 million		$ 600 million
Expansion of rail system 70% (110 MM Tons) @ $20 million		1540
Expansion of barge system 20% (110 MM Tons) @ $5.5 million		120
	Total	$2260 million

1981-1985

Expansion of rail system 70% (130 MM Tons) @ $20 million		$1820
Expansion of barge system 20% (130 MM Tons) @ $5.5 million		140
	Total	$1960 million

1986-1990

One 25 MTPY, 1000-mile coal-slurry pipeline @ $600 million		$ 600 million
Expansion of rail system 70% (70 MM Tons) @ $20 million		980
Expansion of barge system 20% (70 MM Tons) @ $5.5 million		80
	Total	$1660 million

TABLE D-26 (cont.) CAPITAL PEQUIREMENTS

AFTF PATH

1991-1995	
Expansion of rail system 70% (30 MM Tons) @ $ 20 million	$ 420 million
Expansion of barge system 20% (30 MM Tons) @ $5.5 million	30
Total	$ 450 million
1996-2000	
No expansion required	
1976-2000 AFTF TOTAL	$ 6330 million

Note: 70% rail share is 60% all-rail
plus 10% rail-barge

20% barge share is 10% all-barge
plud 10% rail-barge

Tonnages per Table D-23

TABLE D-27 WATER REQUIREMENTS

THREE PATHS

NEE		
1976-1980	Two coal slurry lines @ 5 BGPY	10 BGPY
1981-1985	Four coal slurry lines @ 5 BGPY	20 BGPY
1986-1990	Six coal slurry lines @ 5 BGPY	60 BGPY
1991-1995	Eight coal slurry lines @ 5 BGPY	80 BGPY
1996-2000	Ten coal slurry lines @ 5 BGPY	100 BGPY
FTFB		
1976-1980	One coal slurry line @ 5 BGPY	5 BGPY
1981-1985	One coal slurry line @ 5 BGPY	5 BGPY
1986-1990	Two coal slurry lines @ 5 BGPY	10 BGPY
1991-1995	Two coal slurry lines @ 5 BGPY	10 BGPY
1996-2000	Two coal slurry lines @ 5 BGPY	10 BGPY
AFTF		
	(Same as for FTFB)	

TABLE D-28 STEEL REQUIREMENTS

NEE PATH

		Million Tons
1976-1980		
Two 1000-Mile Pipelines @ 430 Tons/ Mile		0.86
100-Ton Hopper Cars: 70% (220 MM Tons) @ 375 Cars/MM Tons = 57,800 Cars @ 30 Tons/Car		1.73
1500-Ton River Barges 20% (220 MM Tons) @ 20 Barges/MM Tons =880 Barges @ 285 Tons/Barge		0.25
	Total	2.84
1981-1985		
Four 1000-Mile Pipelines @ 430 Tons/Mile		1.72
100-Ton Hopper Cars 70% (180 MM Tons) @ 375 Cars/MM Tons = 47,200 Cars @ 30 Tons/Car		1.42
1500-Ton River Barges 20% (180 MM Tons) @ 20 Barges/MM Tons =720 Barges @ 285 Tons/Barge		0.21
	Total	3.35

TABLE D-28 (cont.) STEEL REQUIREMENTS

NEE PATH

		Million Tons
1986-1990		
Five 1000-Mile Pipelines @ 430 Tons/Mile		2.15
100-Ton Hopper Cars 70% (180 MM Tons) @ 375 Cars/MM Tons =47,200 Cars @ 30 Tons/Car		1.42
1500-Ton River Barges 20% (180 MM Tons) @ 20 Barges/MM Tons =720 Barges @ 20 Tons/Barge		0.21
	Total	3.78
1991-1995		
(Same Set of Calculations as in 1986-1990)		
	Total	3.78
1996-2000		
Five 1000-Mile Pipelines @ 430 Tons/Mile		2.15
100-Ton Hopper Cars 70% (250 MM Tons) @ 375 Cars/MM Tons =65,600 Cars @ 30 Tons/Car		1.97
1500-Ton River Barges 20% (250 MM Tons) @ 20 Barges/ MM Tons = 1000 Barges @ 285 Tons/Barge		0.28
	Total	4.40
	1976-2000 NEE TOTAL	18.15

See Notes to Table D-24

TABLE D-29 STEEL REQUIREMENTS

FTFB SCENARIO

		Million Tons
1976-1980		
One 1000-Mile Pipeline @ 430 Tons/Mile		0.43
100-Ton Hopper Cars 70% (100 MM Tons) @ 375 Cars/MM Tons =26,200 Cars @ 30 Tons/Car		0.79
1500-Ton River Barges 20% (100 MM Tons) @ 20 Barges/MM Tons =400 Barges @ 285 Tons/Barge		0.11
	Total	1.33
1981-1985		
100-Ton Hopper Cars 70 % (130 MM Tons) @ 375 Cars/MM Tons = 34,100 Cars @ 30 Tons/Car		1.02
1500-Ton River Barges 20% (1300 MM Tons) @ 20 Barges/MM Tons = 520 Barges @ 285 Tons/Barge		0.15
	Total	1.17
1986-1990		
One 100-Mile Pipeline @ 430 Tons/Mile		0.43
100-Ton Hopper Cars 70% (70 MM Tons) @ 375 Cars/MM Tons =18,400 Cars @ 30 Tons/Car		0.55
1500-Ton River Barges 20% (70 MM Tons) @ 20 Barges/MM Tons =280 barges @ 285 Tons/Barge		0.08
	Total	1.06

TABLE D-29 (cont.) STEEL REQUIREMENTS

FTFB SCENARIO

		Million Tons
1991-1995		
100-Ton Hopper Cars 70% (120 MM Tons) @ 375 Cars/MM Tons =31,500 Cars @ 30 Tons/Car		0.94
1500-Ton River Barges 20% (120 MM Tons) @ 20 Barges/MM Tons =480 Barges @ 285 Tons/Barge		0.14
	Total	1.08
1996-2000		
(Same calculations as 1986-1990)	Total	1.06
	1976-2000 FTFB TOTAL	5.70

See Notes to Table D-25

TABLE D-30 STEEL REQUIREMENTS

AFTF PATH

	Million Tons
1976-1980	
One 1000-Mile Pipeline @ 430 Tons/Mile	0.43
100-Ton Hopper Cars 70% (110 MM Tons) @ 375 Cars/MM Tons =28,900 Cars @ 30 Tons/Car	0.87
1500-Ton River Barges 20% (110 MM Tons) @ 20 Barges/MM Tons =440 Barges @ 285 Tons/Barge	0.12
Total	1.42
1981-1985	
(Same as for FTFB 1981-1985)	
Total	1.35
1986-1990	
(Same as for FTFB 1986-1990)	
Total	1.06

TABLE D-30 (cont.) STEEL REQUIREMENTS

AFTF PATH

		Million Tons
1991-1995		
100-Ton Hopper Cars 70% (30 MM Tons) @ 375 Cars/MM Tons =7,900 Cars @ e0 Tons/ Car		0.24
1500-Ton River Barges 20% (30 MM Tons) @ 20 Barges/MM Tons =120 Barges @ 285 Tons/Barge		0.03
	Total	0.27
1996-2000		
No expansion		
	Total	None
	1976-2000 AFTF TOTAL	4.10

See Notes To Table D-26

D-5 ELECTRIC ENERGY

Introduction

This section will discuss some of the aspects relative to providing an electric transport system capable of supporting the delivery of electrical energy from generation sites to load centers. For the year 2000, an extrapolation of the 1970 National Power Survey Study (NPS) indicates a need for a 2400 gigawatt transport system [FPC-70]. The Westinghouse Nuclear-Electric Economy Study (NEE) requires a 3000 gigawatt system and the Ford Technical Fix Study (FTFB) a 1300 gigawatt system [Ross-72, Ford-74]. The Alternate Path to the Ford Technical Fix Study (AFTF) requires a 1265 gigawatt system.

Commonly, electric power systems are analyzed by investigating the areas of generation, transmission and distribution. Generation is discussed elsewhere. Transmission will be discussed in detail. Distribution will be discussed in less detail and combined with transmission.

Transmission Design Concept

Prior to the Northeast power failure of 1965, most transmission system design effort was directed at ascertaining that the transmission lines had adequate capacity. After the failure, design shifted to guaranteeing that the transmission system had sufficient integrity to be able to survive severe system disturbances such as the instantaneous loss of a large generating unit or the instantaneous loss of a key transmission line.

Interconnections with other power systems, redundant transmission lines, and excess transmission line capacity are three of many methods used to improve the reliability of a power system. What is of interest is that a particular transmission line is built to perform a specific function in a power system and is built with excess capacity. Designs are now made at the reliability level, not the capacity level.

Transmission Line Mileage

Figure D-4 shows historic mileage growth for transmission lines of voltage levels 230 kV and greater plus a possible mileage growth plan which will support the NPS Study to 1990. An extrapolation of this curve to year 2000 indicates a need for 215,000 miles of transmission line. Descriptions of the transmission line mileage for various voltage levels is given in Table D-31.

Shown also on Figure D-4 is transmission line mileage versus time for the NEE, FTFB, and AFTF paths. The NEE Study requires a larger power capability than the NPS Study. As the power level of a system grows to higher levels, the amount of transmission does not increase linearly since the system will utilize higher level voltages; consequently, the year 2000 prediction for NEE Study is 240,000 miles, the FTFB Study 160,000 miles, and the AFTF Study 150,000 miles.

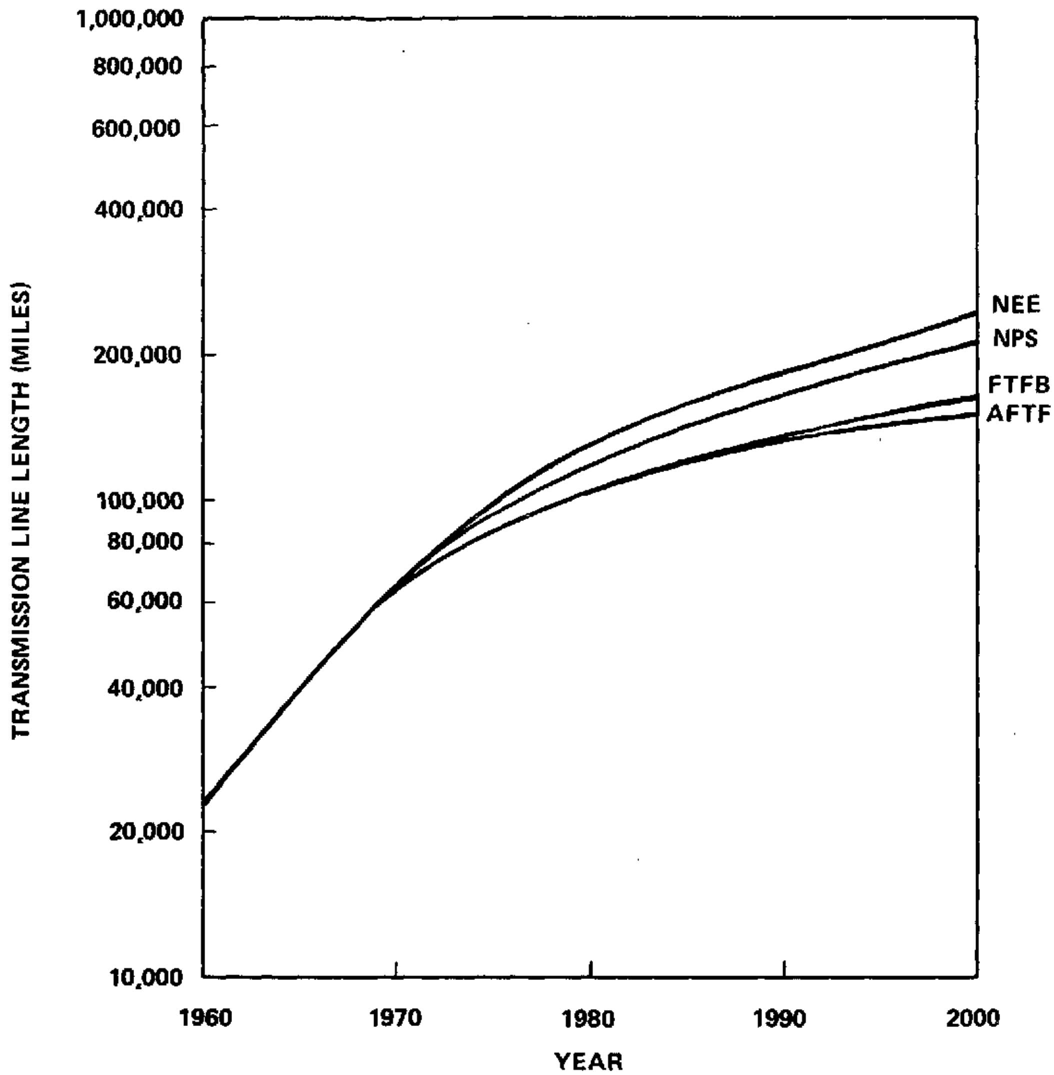


FIGURE D-4 TRANSMISSION LINE MILEAGE VERSUS TIME FOR NPS, NEE, FTFB AND AFTF STUDIES

TABLE D-31 TRANSMISSION LINE MILEAGES IN U.S., 230 kV AND ABOVE [FPC-1970]

	230 kV	287 kV	345 kV	500 kV	765 kV	400 kV (dc)	Total
1940	2,327	647	-	-	-	-	2,974
1950	7,383	791	-	-	-	-	8,174
1960	18,701	1,024	2,641	13	-	-	22,379
1970	40,600	1,020	15,180	7,220	500	850	65,370
1980	59,560	870	32,670	20,180	3,540	1,670	118,490
1990	67,180	560	47,450	33,400	8,940	1,670	159,200

By 1990 there may be significant applications of ac voltages higher than 765 kV and more extensive use of HVDC than that shown in the table.

Land Requirements

The NPS Study requires that an additional 150,000 miles of transmission system be constructed; the NEE 175,000 miles, the FTFB 95,000 miles, and the AFTF 85,000 miles. The Associated University, Incorporated Study indicates that 28,000 square miles of land area would need to be dedicated to electric transmission usage for the NPS system at year 2000 [AUI-72]. Assuming proportional area requirements, 31,300 square miles are required for the NEE, 20,800 square miles for the FTFB, and 19,500 square miles for the AFTF.

It is interesting to note that currently proposed designs of 500 kV, 500 kV double circuit, and 1,100 kV lines utilize right-of-ways that are about the same size as earlier 230 kV lines [EW - 74]. The three designs use widths varying from 120 to 145 feet.

Future transmission lines will be built in areas where land is relatively easy to procure to areas where it is totally unavailable. In the latter locations, underground transmission with its inherent physical problems and its extremely high relative cost will be mandatory.

Material Requirements

Significant amounts of galvanized steel for tower construction, aluminum cable, and insulating materials will be required along with the materials necessary to provide terminal support. Although there is a current shortage of insulator porcelain and malleable iron for insulator supports, no major material problems are anticipated in the proposed transmission systems.

The one factor that is becoming apparent is the need for placing firm orders for materials for delivery two to three years hence. This longer leadtime is new and is likely to become worse; however, it can be accommodated in the planning horizons of the system planners.

Labor Requirements

Data for employment in investor-owned utilities for the period 1960-1970 is given by the Environmental Protection Agency, as reported by the Edison Electric Institute [EPA-73-1]. The data are grouped as Operation and Maintenance (O & M) and Construction. If one assumes that the number of employees involved in O & M is proportional to the investment level of the utilities, the data indicate that

$$N_{O\ \&\ M} = 268.4\ (O\ \&\ M/58.8)$$

where $N_{O\ \&\ M}$ is the number of O & M employees in thousands and (O & M) is the total utility investment in all facilities in billions of dollars.

If one assumes that the number of employees involved in construction within the utilities is proportional to the annual construction expenditure plus

an off-set, the data indicate that

$$N_{construction} = 0.00993 \text{ (Annual Construction)} + 50.3$$

where $N_{construction}$ is the number of utility construction workers in thousands and Annual Construction is the expenditure in millions of dollars. Data for annual construction expenditures are taken from Electrical World [EW-73].

Investor-owned utilities own about 80 percent of the generator capacity in the United States and generate a similar percentage of the total energy. In order to predict the total number of employees for all utilities, both investor-owned and public, the two equations, above, must be multiplied by 1.25.

Utilities contract out most of the high voltage transmission line construction. Contractor labor forces have risen from 170,000 in 1963 to 205,000 in 1974 [EW-74]. Based on a ratio of 39 men/mile derived from FPC data of Table D-31, an additional labor force of 218,000 would be required for the NPS Study at year 2000; for the NEE Study 234,000; and for the FTFB Study only 117,000. Because of the transmission and distribution annual construction must be modified to reflect a small growth rate at the year 2000 for AFTF, a modified prediction of 50,000 in the labor force at year 2000 results. The 117,000 and 50,000 populations represent significant regressions in labor demand.

Historically, degreed engineers are about 3.6 percent of the total manpower employed by all utilities. This percentage is used to determine the utility engineering requirements in the future. This value is also deducted from the total utility manpower plus the contract transmission and distribution labor force in order to arrive at a value for all utility non-engineering labor.

There are two other deductions. These are for non-engineers required to operate fossil fuel electrical generating plants and non-engineers required to operate nuclear generating plants. Values for these employees are accepted from the work forces predicted in Appendix C.

Table D-32 tabulates the required employment levels for years 1980, 1985, 1990, 1995 and 2000 for each of the three energy studies.

Capital Requirements

Electrical World forecasts the cumulative cost of building the additional transmission from 1973 to year 1990 to be $57.4 billion (1973 dollars) [EW-73]. This system is the same as that of the NPS Study. A companion cost is the distribution system to support utilization which will cost 135.9 billion 1973 dollars for the same time interval. By comparison, the total cost of generation, transmission, and distribution will be $480 billion.

Table D-33 shows the cost of transmission, distribution, and the sum for the four studies which covers the interval 1972-2000. The NPS Study results are predicted from an extrapolation ten years forward and one back of the *Electrical*

TABLE D-32 EMPLOYMENT REQUIREMENTS FOR THE THREE ENERGY STUDIES

Year	Net Utility Non-engineering Employees ($\times 10^3$)			Degreed Engineers ($\times 10^3$)		
	NEE	FTFB	AFTF	NEE	FTFB	AFTF
1980	595	627	645	22.4	19.3	20.1
1985	657	731	655	24.6	24.2	20.9
1990	719	633	672	27.0	21.2	22.2
1995	749	637	622	28.9	22.1	22.0
2000	775	657	500	30.9	23.3	19.9

TABLE D-33 CUMULATIVE COST OF TRANSMISSION AND DISTRIBUTION SYSTEMS 1972-2000

Study	Transmission	Distribution	Transmission and Distribution Sum
	(x 10^9 dollars)	(x 10^9 dollars)	(x 10^9 dollars)
NPS	106.6	261.4	368.0
NEE	133.2	326.7	459.9
FTFB	57.8	141.6	199.4
AFTF	55.9	136.9	192.8

World data. The EW data is FPC data for the NPS Study of 1970, converted to 1973 dollars.

The NEE, FTFB, and AFTF values are proportions of NPS values based upon generation capability at year 2000. The values assume that the transmission and distribution system needed to support a given generation capability, both with respect to capacity and to reliability, is proportional to the megawatt generation level.

Table D-34 shows the five year interval cumulative capital investments required for the transmission and distribution systems for the three studies in question. The NEE and FTFB are proportions of the NPS value for the same time intervals. The AFTF values are based on a modified investment trajectory which requires overbuilding the transmission and distribution system in the intervals prior to a leveling off in generation expansion. This modification is necessary in order to have a small annual transmission and distribution investment in year 2000 and to smoothly phase out transmission and distribution construction and investment.

TABLE D-34 FIVE YEAR INTERVAL CAPITAL REQUIREMENTS FOR THE THREE ENERGY STUDIES

Interval	Capital Requirement ($\times 10^9$ dollars)		
	NEE	FTFB	AFTF
1976-80	56.4	24.4	30.2
1981-85	71.2	30.9	38.4
1986-90	86.9	37.5	45.7
1991-95	100.8	43.7	46.7
1996-2000	115.4	50.0	18.2

D-6 TRANSPORTATION OF NUCLEAR FUELS AND WASTES

There has been no effort to analyze the transportation system required to move uranium ores, fuels, and waste material from reactors, for the simple reason that the additional railroads required are essentially nil. The energy density of nuclear fuels, even for the unprocessed ores, is extremely high; and consequently all of the three scenarios, which project greatly increased coal and coal transportation, will have the capacity to transport uranium. The major costs of nuclear generation of electricity are, as pointed out elsewhere, reactors and reactor facilities, processing plants for ores, enrichment plants, waste disposal plants, and electric transmission lines. The costs of transporting nuclear fuels are extremely small compared to these other costs, and will not be computed separately.

This does not mean that the transportation of nuclear fuels and wastes do not have impact on the U.S. Transportation of wastes must be done with tightly sealed containers impervious to major accidents, e.g., train crashes. Further, the system should be resistant to sabotage or theft. One major organization, the Sierra Club, has urged a moratorium on nuclear power plant construction; not because of fears that the plants are unsafe, but rather because nuclear handling facilities are not adequately protected, both from accidents and from sabotage or from nuclear materials thefts by, e.g., groups intent on nuclear blackmail.

D-7 IMPACTS OF ENERGY DISTRIBUTION

D-7-1 TECHNOLOGICAL IMPACTS OF ENERGY DISTRIBUTION

In order to achieve the Nuclear Electric Economy scenario (or any other economy heavily dependent on electricity), the electrical transmission system will undergo tremendous changes, both in terms of the long distance transmission system and in terms of local distribution. A general idea of the extent to which an electric economy will require expanded transmission capabilities can be obtained from Appendix D-5, above. But a simple fact here will illustrate the idea clearly: using present technology and land use requirements, the transmission system will need to increase from the 1970 land use of about 6500 square miles by a factor of 4 to 28,000 square miles in year 2000. The general idea is also indicated in Figures D-5 and D-6 below in which the possible growth of the transmission system to year 1990 is illustrated. It is, of course, easy to say that 28,000 square miles is an extremely small part of the approximately 6,000,000 square miles of land in the lower 48 states. However, there are already many people who oppose, for esthetic reasons, the installation of transmission lines, and an increase by a factor of 4 the total land used will no doubt raise many screams of indignity, particularly in areas of high population, such as the eastern megalopolis, where land is at a premium already. One can imagine readily that technological advances, different concepts of land use, and various esthetic advances may become necessary.

Extra-high voltage (EHV) transmission will no doubt have to become developed technology, in order to achieve the NEE scenario; fortunately, transmission lines at voltages of 700KV and higher will not require much more land (per line) than present systems. But various, probably solvable problems come to the fore, in the areas of circuit breaker technology, insulator technology, and even transformer technology. Larger bundles of cable will become common, in which a single phase of line might have as many as 12 conductors running parallel, as compared to the present 4 cable (maximum) lines. These cables may be necessary to eliminate ozone formation around the lines. In addition, insulator technology changes will probably be required. At present, the insulation integrity of a string of insulators can be endangered by water collection or contamination on one segment of an insulator column supporting a high voltage line. Land use requirements may also bring about greatly increased usage of underground electric transmission lines, particularly in areas of high electricity usage (which are, of course, generally concomitant with high population density). Cryogenic underground transmission lines for which technologies are not at present developed, may be required.

But even in more rural areas, a greatly increased transmission line complex will have effects. Present transmission lines present problems for crop dusters; more lines will lead to more accidents with crop dusting airplanes, and may in turn lead to new agricultural technologies for spraying crops at ground level. In addition, rural transmission lines occasionally are disrupted by frustrated hunters, who choose insulators on transmission lines as targets. More transmission line destruction might well occur in the future than does now, particularly if some of the frustrations envisioned by Toffler in his book Future Shock become common.

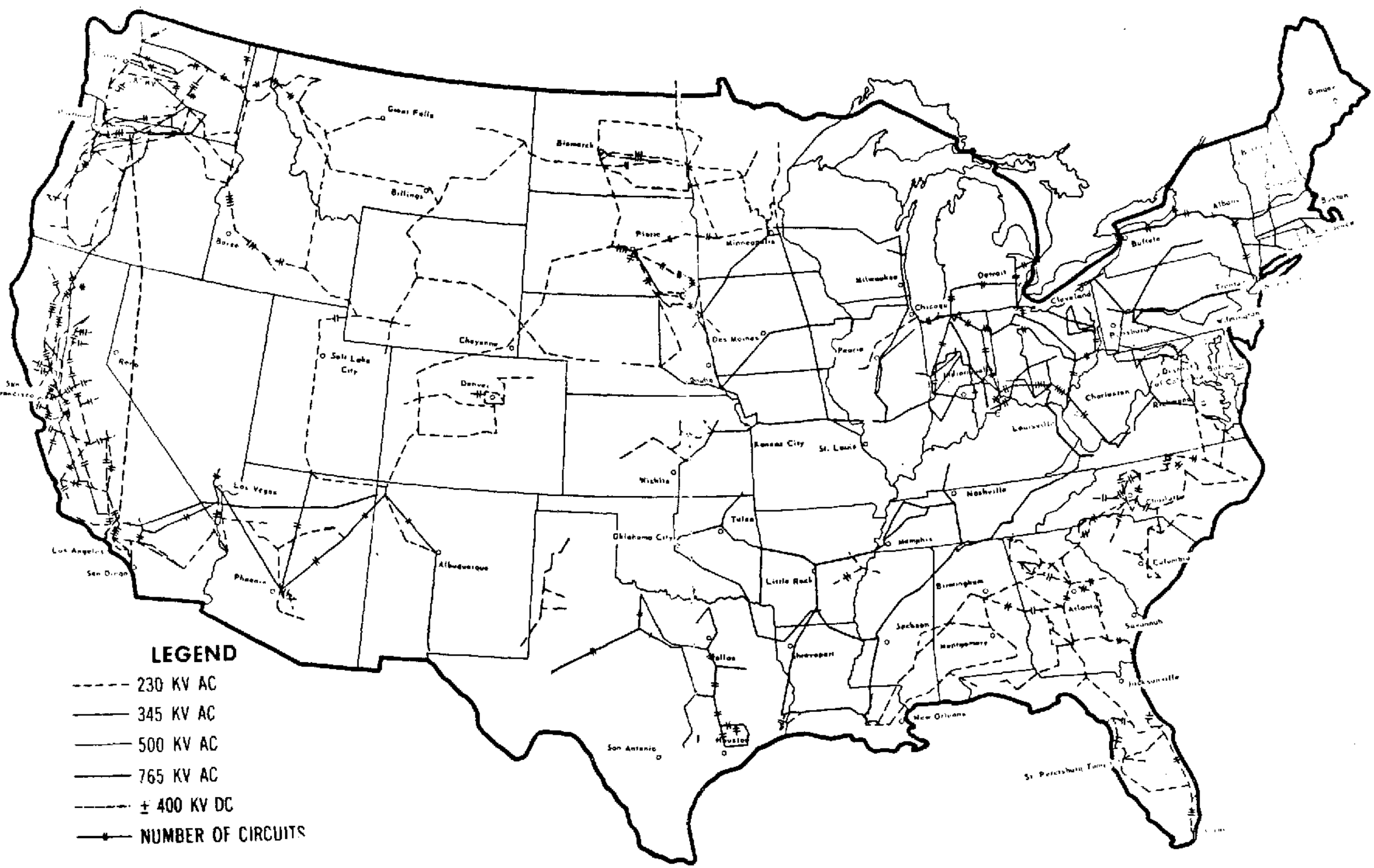


FIGURE D-5 1970 ELECTRIC TRANSMISSION SYSTEM [FPC-70]

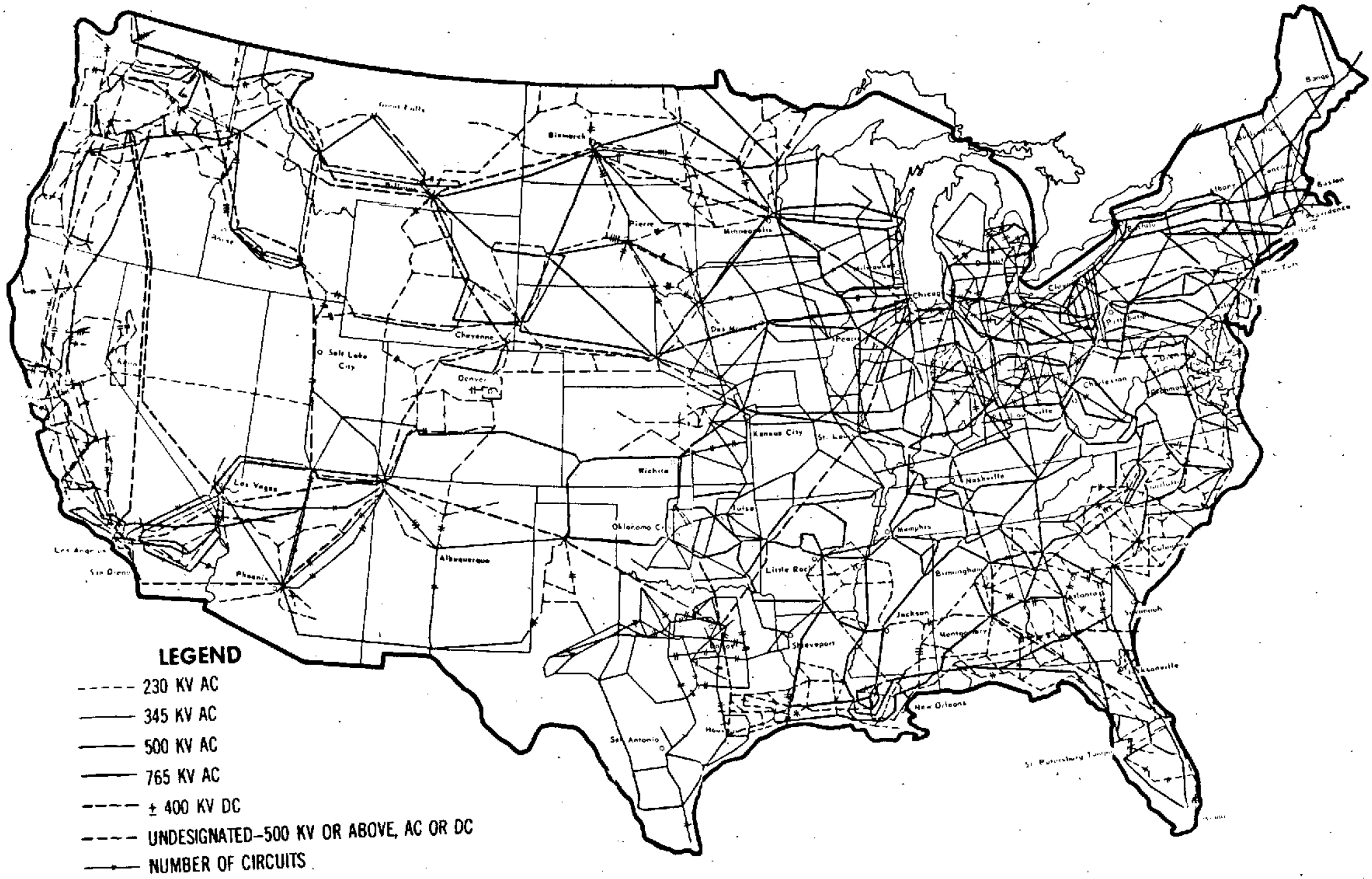


FIGURE D-6 POSSIBLE 1990 ELECTRIC TRANSMISSION SYSTEM [FPC-70]

But it should be pointed out that not all transmission lines have bad impacts. In the western United States, the land under transmission lines is viewed as a benefit by Forest Service personnel, because the long strips of deforested land serve as firebreaks. One can also imagine that as the land requirements for transmission lines increases, the imaginative use of this land will also increase. For example, land under transmission lines in mountains might be used in winter for ski-runs or snow-mobile trails. In urban areas, the land might become valued as plots for vegetable gardens, in the same way that plots of land within cities are presently rented to residents, e.g., the Boston Commons. One would also expect that better land-use planning will result, in order that transmission lines will not traverse particularly scenic areas.

The local distribution requirements of electricity-based economies will also change. One of the suggestions presented in the Westinghouse Nuclear Electric Economy is that electric cars will become necessary. One study on electric cars [Stuhlinger-74], suggests that electric cars can readily be developed for commuter usage. But in the proposal, the short range of electric cars requires that electrical outlets, with meters, be placed in parking lots, so that the cars (built using present battery technology) can be recharged during the day. But if battery technology can be improved so that electric automobiles can achieve greater range, and thereby achieve greater acceptability (Americans seem to require that a car be able to go long distances without refueling, even though cars are generally used for rather short trips), then it is not difficult to image "electricity filling stations", at which large amounts of electrical energy can be "pumped" into cars quickly. Should this happen, the nation would experience a reduced necessity for gasoline tanker trucks and associated apparatus.

But there are impacts in areas other than those caused by transmission and distribution of electrical energy. Within the scenarios, there is a need for considerably increased coal transportation, both by coal-slurry pipelines and by barges. Coal-slurry pipeline technology has often been used in the past as a threat by coal companies, to convince the railroads to reduce their rates. But should there be a significant increase in coal-slurry pipelines, one can image several technological impacts. First of all, slurry dewatering techniques would likely be improved. There is also the question of where the water will come from; it certainly is possible that coal-slurry pipelines will be paralleled by water pipelines, in which the water goes toward the mine from the coal-use area in a closed cycle, particularly when the coal comes from water-deficient areas. Increased uses of pipeline could well cause competition for pipeline steel, leading to increased pipe capacity by the steel companies. Technologies for stripping the ash from coal, before the coal is inserted into the pipeline, might also be developed. Such techniques would be highly advantageous, because the ash could conceivably be disposed of within the mine, reducing land pollution and water pollution near power plant sites. Long distance coal-slurry pipelines will also require the development of large pumps. In addition, increased barge usage will create impacts. Improved on- and off-loading equipment may need to be developed. Increased barge transportation in general could lead to wider river channels which will produce less river flow resistance. Flood crest prediction techniques may have to be improved. More dredging equipment will be needed.

D-7-2 ENVIRONMENTAL IMPACTS OF ENERGY TRANSPORTATION

All forms of energy transportation may produce environmental damage. In some cases, the damage may be quite obvious, as in the case of oil spills, and in other cases, the damage may be subtle, as in the case of electrical transmission lines. The particular impacts that will be most serious depend, of course, on the particular scenario. In general, less energy transported results in less environmental damage.

The transportation of oil presents potentially nasty damage to the environment. As is well known, the Alaska pipeline was delayed for about 5 years, and final approval was given because a national emergency was perceived, not because all the concerns of environmentalists had been allayed. The potential damage to U.S. coastline by tanker accidents and by offshore drilling accidents is also considerable. The areas that may be affected by using north slope Alaska oil are shown in Figure D-7. A good review of the oil spills in the world, due to tanker offshore drilling and pipeline operations is found in the work by Kash et al. [Kash-73]. This work concludes that oil obtained from the Alaska north slope, and transported via the TAPS pipeline and tanker to the lower 48, will be environmentally far more damaging than oil obtained in outer continental shelf drilling operations. Similar damage to the environment will no doubt accrue from trans-Canadian gas pipelines. Information on the ecological damage, resulting from far north pipelines may be obtained from various conservation groups, e.g., the Sierra Club, Friends of the Earth, The Wilderness Society, or a variety of Canadian societies.

Tanker transportation of oil presents the possibility of serious environmental damage quite different from the damages that pipelines may cause. Supertankers are extremely efficient at transporting energy--but they also present the possibility of major localized damage. If a supertanker should break up near shore, particularly near a marsh estuary, damage could be caused to all forms of biological life that might not be repaired for decades. In addition, the standard practice of oil tankers to flush their tanks while at sea produces wide-spread pollution of the oceans. The severity of this pollution and the eventual effects of this pollution on sea life remain largely unknown. Additional research on this particular problem is needed; research on better ways for tankers to clean their tanks is also needed.

LNG tankers also present the potential for damage quite unlike any previously encountered. It may not be fair to present as a real impact the worst case imaginable, but the potential for damage from LNG tankers is enormous. If an LNG tanker were gouged in some way (either through navigational error, sabotage, or collision with another ship) such that the tanks began leaking badly, the escaping gas could fill the air for an extensive area. Should this happen, a tremendous explosion could occur.

The environmental consequences of electrical transmission lines seem, at present, to be inconsequential, other than the visual damage. There is, of course, the possibility that the clearing of the trees under transmission lines could lead to erosion problems in some areas, but severe erosion problems seem rather unlikely, particularly since transmission line right

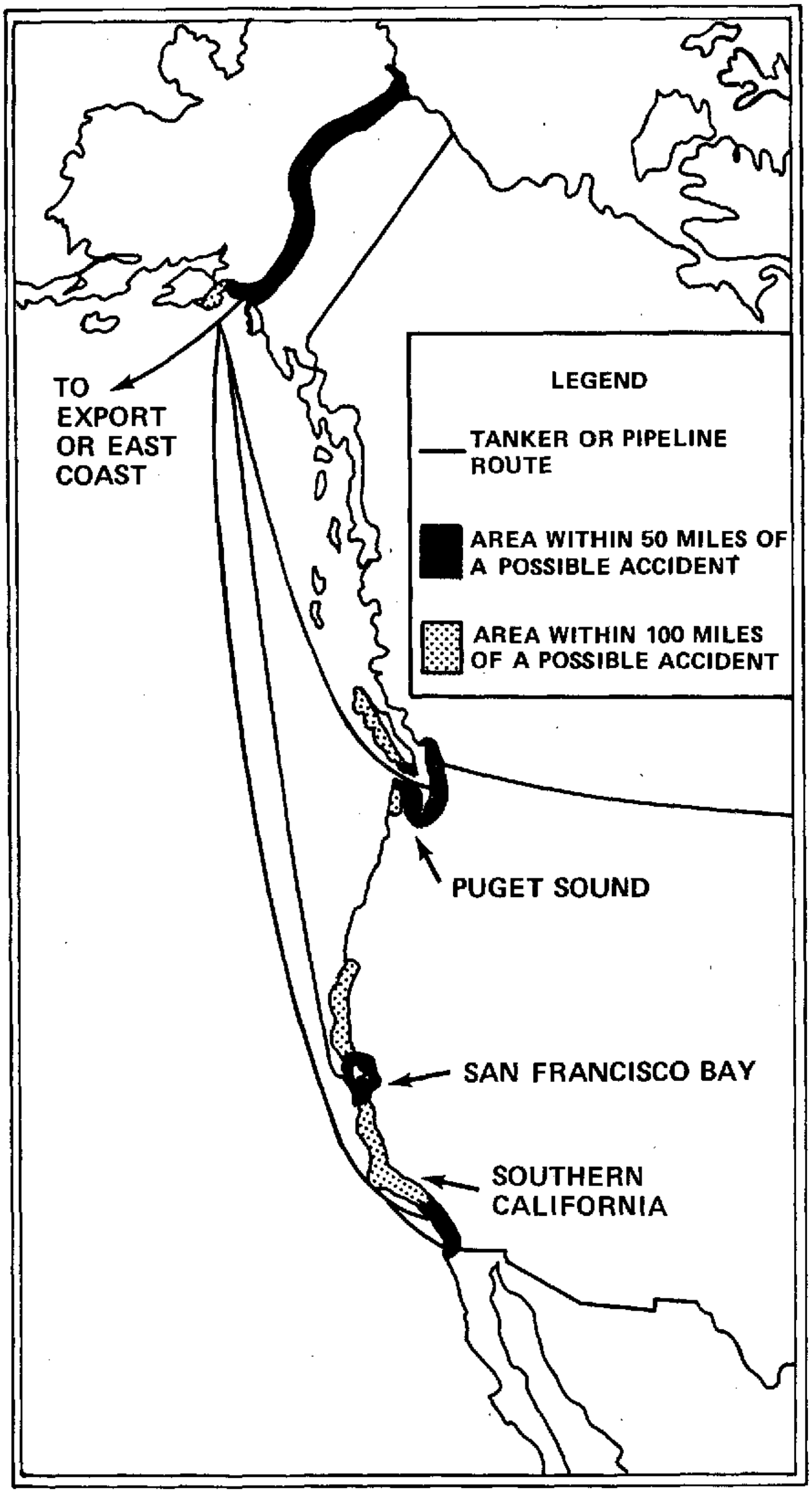


FIGURE D-7 POTENTIAL OIL-SPILL DAMAGE AREAS, FOR OIL MOVED FROM PRUDHOE BAY TO LOWER 48 STATES [Kash-73]

of ways are examined on a regular basis. However, there may possibly be more subtle environmental damage from high voltage transmission lines. Some biophysicists have suggested that the low frequency radiation surrounding transmission lines could conceivably cause biological damage in animal life, through interference with nervous systems in animals, or other non-thermal, non-ionizing effects. Should this be true, it might prove necessary to place fences along the sides of a transmission line right of way, as a matter of practice, to prevent animals from traveling under lines. The protection of birds might prove more difficult; underground lines, and the concurrent large additional expense (up to a factor of perhaps 20) might be necessary.

The proliferation of barge transportation also has potential adverse environmental effects. The precise effects on river basins of extra channel widths are not adequately studied. But it is clear that channelization of small streams upsets environmentalists, when they examine the results on surrounding countryside. In addition, barges are a source of water pollution and air pollution from engine exhausts and wave erosion.

D-7-3 ECONOMIC IMPACTS OF ENERGY TRANSPORTATION

One fact is clear: bringing energy to the major market areas in the United States is becoming very expensive. Fortunately, the dangers of relying on foreign sources of energy have been made quite clear to the American public, even though it is a popular belief that American oil companies used the Arab oil embargo as an excuse to raise prices. (One of the speakers at the seminars held by this study group, Mr. M. F. Simon, from the Electricite de France, jokingly referred to "that little war you arranged" in the Middle East). But quite apart from the facts that significant oil company profit increases began after the embargo, and apart from the fact that foreign sources of energy are inherently interruptible, there are significant dangers to the American economy should a significant fraction of our energy come from foreign sources. The question arises very quickly, how do we repay oil producing countries which sell us billions of dollars worth of imports each year? The possible answers to this question and consequences of various economic results are still being debated. Suffice it to say that very likely few Americans would be willing to accept the necessary changes in our economic institutions, e.g., large ownership shares by foreigners of U. S. enterprises.

But even without reliance on foreign sources of energy, energy is becoming more expensive -- and not merely because energy usage is rising but also because the unit costs of getting the energy from where it is found to the end use locations is also getting more expensive. The Alaska pipeline is a prime example: the presently estimated cost of the Alaska pipeline, of $4.5 billion, makes it the single largest project ever undertaken by private industry in America. And the proposed gas pipeline, to bring gas from Prudhoe Bay to the lower 48 states markets, will cost almost twice as much! Not only does the expense of projects such as this create inevitably higher prices for customers of gas and oil, but in addition there will be a restructuring of the American economy. Francis H. Schott has expressed the problem clearly: "Even before the Arab oil embargo, responsible estimates for the decade ahead suggested that the combined capital requirements of the energy and utility industries would necessitate a major

increase in these industries' share of total corporate externally raised long-term funds. This share has averaged slightly above 20 percent in the past decade" [Schott-73].

Economic changes are already taking place within the gas utility industry. The gas utilities have historically been involved only in the transportation of energy; they depended on the various oil producers for their sources of gas. Consequently, the function of the gas utilities has been to purchase gas from producers, and then provide the pipelines to take the gas from the wells to the users. Heavy investments were made at the distribution end of the system. Now that gas supplies are dwindling, gas utilities are taking it upon themselves to become producers, in addition, they are moving into gas exploration and drilling operations. And since drilling operations are fundamentally risky (large sums of money can be spent on dry holes), gas companies are beginnning to move from economic arrangements where their profits are relatively easy to predict, to economic situations where large capital expenditures are being made without guarantee of profit. It is conceivable that the effect of these actions may ultimately be to reduce the capital investment gas utilities can expect from traditional sources, e.g., investors who look for assured long-term income.

Subtler economic changes may also occur as the result of energy transportation. Coal-slurry pipelines are not at present a widely-used means of transporting coal. The expanded use of coal-slurry lines, as envisioned in the scenarios presented in D-4, above, could cause new economic competition. Coal pipeline requirements for pipe could cause enough competition to drive up the prices for pipe. Water requirements could cause significantly increased water prices, particularly for coal lines carrying coal from western mines in Montana, the Dakotas, or Wyoming, where water is relatively scarce. Coal pipelines could even lead to revenue loss for railroads, should pipelines become a common mode of coal transportation in strong rail service areas.

The economic impacts of electricity transmission lines, apart from the capital requirements, could have subtle effects. People do not like to live near electric transmission lines. In residential areas, lines might possibly lead to lowered property values; if these reduced property values lead to reduced property tax revenue for cities (probably small cities would experience this problem), these cities might try to recoup revenue losses by placing new taxes on the utilities. Or conversely, should high property values in certain localities (particularly in dense urban areas) restrict the ability of utilities to purchase right of way, the utilities might possibly seek state aid. Condemnation of right-of-way for transmission lines could occur, much as condemnation is used to procure land for highway construction now.

D-7-4 SOCIAL AND POLITICAL IMPACTS OF ENERGY DISTRIBUTION

All modes of energy distribution but especially gas utilities, electric power companies, and railroads, are presently subject to various forms of governmental regulation, on both the Federal and local levels. In addition, there have recently been governmental actions, and recommendations for action, that have further regulated the oil producers (e.g., pricing regulations, including recent Congressional efforts, vetoed by the President, to legislate lower gasoline prices). In addition, foreign governments are going to be increasing drawn into regulation, e.g.: Canadian National Energy Board permission will be required before construction can begin on any gas pipelines crossing through Canada.

There are good arguments for both more and less regulation of the energy transporting industries. One of the primary calls by the American Gas Association is that there should be the elimination of governmental control of the well-head price of gas [AGA-73]. The object of such price control deregulation would be to provide incentives for the exploration and development of natural gas resources. Proponents of this argument point to the fact that interstate buyers of gas cannot compete with intrastate buyers who may resell at prices that are not controlled by the Federal Power Commission. In addition, there are long-standing claims that the major problem with railroads has been too much governmental control of rates and that Corps of Engineers waterway construction subsidizes the barge companies.

On the other hand, there seem to be many good arguments for increased government regulation, and especially in areas of international transportation. There is no doubt that oil tankers are polluting the oceans. As mentioned above, the extent of long-lasting ocean damage accruing from tanker operations is unclear. But there is no doubt that the problems in this area cannot be solved, controlled, or even researched adequately without substantive international cooperation. Such problems may call for a complete restructuring of international attitudes. It seems to be a truism, which can no doubt be applied to governments, that the people most concerned about pollution are those with relatively large incomes. Lacking international cooperation, there is still room for governmental regulation of tankers operating between American ports; at present, tankers can escape regulations by simply operating outside of territorial limit.

Within the United States, a complete restructuring of governmental regulatory agencies is a possible approach. Since the different forms of energy transportation come under different regulatory agencies, it would seem to be desirable to combine all the regulatory agencies under one roof. But more than this is required: if national energy policy is developed, with a governmental agency to oversee implementation of such a policy, then one can see that many attitudes may have to be revised. If, for example, it is determined that the nation needs more of a particular form of energy, then extensive governmental encouragement (via tax measures and a variety of other possible governmental actions for particular industries may be required. Such actions do occur now: the Atomic

Energy Commission feels that one of its duties is to encourage, actively, the construction of nuclear power plants. On the other hand, if a particular form of energy is deemed unnecessary or environmentally damaging, governmental action might be required to eliminate some industries, but at present, there is no consistent approach to energy. Arguments have been made, for example, that if the government had put as much time and money into encouraging solar energy as atomic energy, the nation would have no present energy problems. Whatever the validity of such arguments, it is clear that the approach to energy development has not been even-handed, or more precisely, has been non-existent in some cases.

On the other hand, there are many people who would argue that the best policy for the government would be to get out of the energy industry and transportation regulation business altogether. But even a change of governmental policy in this direction might produce unexpected impacts. The government is at the time heavily involved in the subsidization of the various transportation segments, ranging from the construction of highways (a considerable area of subsidization to the trucking industry) to the outright operation of air control facilities for the airlines. Other subsidization has been called boon-doggling: the barge waterway leading from the Mississippi river into Oklahoma has been so labeled by many. The point of this discussion is not that such subsidization is good or bad, but that a shift toward complete or partial deregulation of transportation industries will require significant changes in attitude. "Pork-barrel" projects, a favorite of Congressmen, may have to be eliminated regardless of the economic advantages to be gained. Good research on highway use wear and tear by traffic might reveal that trucks produce far more (or far less) damage than automobiles; conclusions either way would require, if subsidization is to be reduced or eliminated, new taxing or other financial arrangements (e.g., toll stations on the interstate highway system). And of course, complete deregulation of all transportation modes could lead in time to the various inequities which brought about the demands for governmental regulation in the first place.

APPENDIX E ENERGY END USE

E-1 INTRODUCTION

The data contained in the tables of Section 1 of Appendix E are intended to display the present situation in four areas:

Energy end uses and sources;

Basic and critical materials;

Population; and

Manpower in both engineering and industrial production.

The data are introduced by brief narratives which point to salient features of the data, but the principal uses of the data appear in Chapter 4, of the text rather than this appendix.

E-1-1 ENERGY END USES: THE PRESENT

In our examination of energy scenarios, there are two initially defined points, one is a future point and the other is the present. The tables will provide a data "base point" for the present and provide some elaboration on energy sources and consumption sectors in end uses and electrical generation.

The energy sources considered are:

Fossil

- coal
- petroleum
- oil
- gas

Non-Fossil

- hydro
- nuclear

The consumption sectors considered are:

Residential/Commercial

Industrial

Transportation

Electrical Generation

The residential/commercial sector can be divided into energy application which are very similar. Energy application cán be divided into five areas in the residential and six in commercial.

Residential

Space Heating
Air Conditioning
Cooking
Water Heating
Lighting and Small Applicances

Commercial

Space Heating
Air Conditioning
Cooking
Water Heating
Lighting
Refrigeration

Space heating, water heating, and air conditioning consume approximately 80 percent of the energy in the residential applications. The corresponding consumptions are similar in commercial.

The residential/commercial sector has dominated the growth in electrical use, therefore, this sector drives the attendant waste of energy inherent in present electrical generating processes.

The industrial sector can be divided into major consumers of energy; they are:

Primary metals

Chemicals

Petroleum refining

Paper

Foods

Stone, clay, glass and concrete

Other

The primary metals and chemical industries are the largest energy consumers in the industrial sector and process steam and direct heating are the two greatest uses of energy (approximately 70 percent) in this sector.

The transportation sector can also be divided into the principal consumers of energy; they are:

Automobiles

Trucks

Aircraft

Ships

Railroads

Other

The combined consumption by autos and trucks is greater than 70 percent, the personal automobile, however, consumes a majority of all the energy in the transportation sector. Because of the low efficiencies of the internal combustion engine, the personal automobile "drives" the waste of energy in this sector.

Electrical generation is typically not an end use, but a conversion process. However, it is a major consumer of fuels. Fossil fuel sources are the dominant fuel source for electric power generation, consuming approximately 80 percent of the fuel inputs in this sector. Non-fossil, hydro and nuclear, is a small portion of the fuel inputs for electrical generation, but the nuclear source is the fastest growing single fuel source used for electrical generation.

The reference for Tables E-1 through E-25 is [Dupree-72] unless otherwise noted.

TABLE E-1 GROSS AND NET ENERGY INPUTS IN TRILLIONS OF BTU (1971)

Net Energy Consumption	
Non-fuel uses[a]	3,957
Percent of total	5.7
Three-sector energy uses[b]	53,096
Percent of total	77.0
Total Net Energy	57,053
Percent of total	82.7
Conversion Losses[c]	
Electrical Sector	11,936
Percent of total	17.3
Total Conversion Losses	11,936
Percent of total	17.3
Total Gross Energy Input	68,989

a) This refers primarily to asphalt and road oil in the residential and commercial sector, chemical feedstocks in the industrial sector and lubes and greases in the transportation sector.

b) The three sectors are the residential and commercial, industrial, and transportation. These are the end uses of energy in the economy. Electrical production converted to BTU on the basis of 3,412 BTU/kWh and synthetic gas converted on the basis of 1,000 BTU/cu. ft. are distributed among these sectors.

c) Conversion losses refer to those losses caused by converting a primary energy source to a secondary energy source.

TABLE E-2 SELECTED U.S. ECONOMIC AND ENERGY INDICATORS (1971)

Gross Energy Inputs (Quadrillion BTU)[b]	69.0
Net Energy Inputs (Quadrillion BTU)[b]	57.0
Population (Million)	207.0
Gross National Product (Millions of 1971 dollars)	1050.4
Energy/GNP Ratio (Thousands of BTU per 1971 dollars)	65.7
Gross Energy/Capita Ratio (Millions of BTU per person)	333.3
Net Energy/Capita (Millions of BTU per person)	275.4
Efficiency Factor (Percent)[c]	82.7

a) Gross energy inputs refers to the total energy inputs to all sectors.

b) Net energy inputs refers to the direct energy going to the Industrial, Transportation, and Household and Commercial sectors plus electrical energy converted on the basis of 3,412 BTU/kWh.

c) Refers to the overall efficiency of conversion of gross energy to the form used by the final consuming sectors. Equal to net energy/gross energy.

TABLE E-3 SELECTED UNITED STATES ECONOMIC AND ENERGY INDICATORS (1970-71)

Year	Gross energy input[a] (Quadrillion BTU)	Net energy input (Quadrillion BTU)	Population (Millions)	Gross National Product (Billion of $ 1958)	Energy/GNP (1000's of BTU)	Gross energy/capita (Millions of BTU)	Net energy/capita (Millions of BTU)	Conversion Efficiency[c] (Percent)
1970	67.4	56.0	204.8	720.0	93.6	329.1	273.6	83.1
1971	69.0	56.9	207.0	741.7	93.0	333.3	274.8	82.7

a) Gross energy is the total of inputs into the economy of the primary fuels (petroleum, natural gas, and coal, including imports) or their derivatives, plus the generation of hydro and nuclear power converted to equivalent energy inputs.

b) Net energy is the sector inputs (household and commercial, transportation, and industrial), and consists of direct fuels and purchased electricity.

c) The conversion efficiency factor is the percent of total gross energy going into the sectors.

TABLE E-4 GROSS ENERGY INPUTS IN TRILLIONS OF BTU (1971)

Energy Source	
Coal	12,660
Petroleum	30,492
Natural Gas	22,734
Nuclear Power	405
Hydropower	2,798
Total	68,989

TABLE E-5 U.S. CONSUMPTION FOR ENERGY RESOURCES BY MAJOR SOURCES (1971)

Petroleum (includes natural gas liquids)	
Million barrels	5,523
Million barrels per day	15.1
Trillion BTU	30,492
Percent of gross energy inputs	44.1
Natural Gas	
Billion cubic feet	22,050
Trillion BTU	22,734
Percent of gross energy inputs	33.0
Coal (bituminous, anthracite, lignite)	
Thousand short tons	510,800
Trillion BTU	12,560
Percent of gross energy inputs	18.2
Hydropower	
Billion kilowatt-hours	266.3
Trillion BTU	2,798
Percent of gross energy inputs	4.1
Nuclear power	
Billion kilowatt-hours	37.9
Trillion BTU	405
Percent of gross energy inputs	.6
Total Gross Energy Inputs	
Trillion BTU	68,980

TABLE E-6

DEMAND FOR ENERGY INPUTS TO HOUSEHOLD AND COMMERCIAL SECTOR, 1971

Fossil Fuels	
Coal[a]	
Millions of tons	14.6
Trillions of BTU	390
Percent of total[b]	2.2
Petroleum	
Fuel Uses	
Millions of barrels	982.4
Trillions of BTU	5,435
Non-fuel Uses	
Millions of barrels	167.2
Trillions of BTU	1,110
Total Petroleum	
Millions of barrels	1,149.6
Trillions of BTU	6,545
Percent of total[b]	37.5
Natural Gas[a]	
Billions of cubic feet	7,125.0
Trillions of BTU	7,346
Percent of total[b]	42.2
Total Direct Fossil Fuels	
Trillions of BTU	14,281
Percent of total[b]	81.9
Electricity Purchased	
Billions of kWh	926.1
Trillions of BTU	3,160
Percent of total[b]	18.1
Total Sector Energy Input	
Trillions of BTU	17,441

[a]No non-fuel uses.

[b]Refers to percentages of total energy inputs to sector.

TABLE E-7 ENERGY INPUTS TO INDUSTRIAL SECTOR (1971)

Fossil Fuels	
<u>Coal</u>	
Fuel Uses	
Millions of tons	159.4
Trillions of BTU	4,332
Non-fuel Uses	
Millions of tons	4.9
Trillions of BTU	133
Total Coal	
Millions of tons	164.3
Trillions of BTU	4,465
Percent of total[a]	19.7
<u>Petroleum</u>	
Fuel Uses	
Millions of barrels	569.4
Trillions of BTU	3,363
Non-fuel Uses	
Millions of barrels	412.6
Trillions of BTU	2,028
Total petroleum	
Millions of barrels	982.0
Trillions of BTU	5,391
Percent of total[a]	23.8
<u>Natural Gas</u>	
Fuel Uses	
Billions of cubic feet	9,460
Trillions of BTU	9,753
Non-fuel Uses	
Billions of cubic feet	665
Trillions of BTU	685
Total natural gas	
Billions of cubic feet	10,125
Trillions of BTU	10,438
Percent of total[a]	46.1
Total Direct Fossil Fuels	
Trillions of BTU	20,294
Percent of total	89.6
Electricity Purchased	
Billions of kWh	682.6
Trillions of BTU	2,329
Percent of total[a]	10.4
Total Sector Energy Input	
Trillions of BTU	22,623

a) Refers to percentage of total energy inputs to sector.

TABLE E-8 ENERGY INPUTS TO THE TRANSPORTATION SECTOR (1971)

Fossil Fuels	
Petroleum	
Millions of barrels	3,004.9
Trillions of BTU	16,139
Percent of total[a]	95.0
Natural Gas	
Billions of Cubic feet	800
Trillions of BTU	825
Percent of total[a]	4.9
Total Fossil Fuels	
Trillions of BTU[b]	16,971
Percent of total[a]	99.9
Utility Electricity	
Billions of kWh	5.34
Trillions of BTU	18
Percent of total[a]	.1
Total Energy Inputs	
Trillions of BTU[b]	16,989

a) Refers to percentage of total energy inputs to sector.

b) Includes coal: 7 trillion BTU.

TABLE E-9 UNITED STATES TOTAL GROSS CONSUMPTION OF ENERGY RESOURCES BY MAJOR SOURCES AND CONSUMING SECTORS IN TRILLIONS OF BTU (1971)

	Coal	Petroleum	Natural gas	Total fossil fuels	Nuclear power	Hydropower	Total gross energy inputs	Total four sector inputs	Utility elec. distributed	Total three sector inputs
Household & Commercial	390	6,545	7,346	14,281	-	-	14,281	14,281	3,160	17,441
Industrial	4,465	5,391	10,438	20,294	-	-	20,294	20,294	2,329	22,623
Transportation	7	16,139	825	16,971	-	-	16,971	16,971	18	16,989
Electrical Generation	7,698	2,417	4,125	14,240	405	2,798	17,443	17,443	(5,507)	-
Total	12,560	30,492	22,734	65,786	405	2,798	68,989			

a) Includes anthracite, bituminous, and lignite

b) Petroleum products refined and processed from crude oil, includes still gas, liquefied refinergy gas, and natural gas liquids

TABLE E-10 UNITED STATES TOTAL GROSS CONSUMPTION OF ENERGY RESOURCES IN STANDARD PHYSICAL UNITS BY MAJOR SOURCES AND CONSUMING SECTORS (1971)

Consuming Sector	Coal[a] million short tons	Petroleum[b] million barrels	Natural Gas billion cubic feet	Nuclear power million Kilowatt-hours	Hydropower million kilowatt-hours	Utility electricity distributed million kilowatt-hours
Household and Commercial	14.6	1,149.6	7,125.0			926,100
Industrial	164.3	982.0	10,125.0			682,560
Transportation	0.3	3,004.9	800.0			5,340
Electrical Generation	331.6	386.9	4,000.0	37,899	266,320	(1,614,000)
Total	510.8	5,523.4	22,050.0	37,899	266,320	

a) Includes anthracite, bituminous, and lignite coals.

b) Petroleum products refined and processed from crude oil, including stil gas, liquefied refinery gas, and natural gas liquids

TABLE E-11 U.S. TOTAL GROSS CONSUMPTION OF ENERGY RESOURCES BY MAJOR SOURCES[a] IN TRILLIONS OF BTU (1970-71)

Year	Anthracite	Bituminous coal and lignite	Natural gas, dry[b]	Petroleum[c]	Total fossil fuels	Hydropower[d]	Nuclear power[d]	Total gross energy inputs	Percentage change from prior year
1970	210	12,712	22,029	29,614	64,565	2,650	229	67,444	+3.8
1971	185	12,375	22,734	30,492	65,786	2,833	391	69,010	+2.3

a) Gross energy is that contained in all types of commercial energy at the time it is incorporated in the economy, whether the energy is produced domestically or imported. Gross energy comprises inputs of primary fuels (or their derivatives), and outputs of hydropower and nuclear power converted to theoretical energy inputs. Gross energy includes the energy used for the production, processing, and transportation of energy power.

b) Excludes natural gas liquids.

c) Petroleum products including still gas, liquefied refinergy gas, and natural gas liquids.

d) Outputs of hydropower (adjusted for net imports or net exports) and nuclear power converted to theoretical energy inputs calculated from national average heat rates for fossil-fueled steam-electric plants provided by the Federal Power Commission. Energy input for nuclear power in 1971 is converted at an average heat rate of 10,660 BTU per net kilowatt-hour based on information from the Atomic Energy Commission. Excludes inputs for power generated by nonutility fuel-burning plants, which are included within the other consuming sectors.

TABLE E-12 PERCENTAGE CHANGE IN U.S. TOTAL GROSS CONSUMPTION OF ENERGY RESOURCES BY MAJOR SOURCES (1970-71)

Year	Anthracite	Bituminous coal and lignite	Natural gas, dry	Petroleum	Total Fossil Fuels	Hydropower	Nuclear power	Total gross energy inputs
1970	-6.3	+1.6	+4.8	+4.2	+3.8	-0.3	+56.8	+3.8
1971	-11.9	-2.7	+3.2	+3.0	+1.9	+6.9	+70.7	+2.3

TABLE E-13 U.S. TOTAL PRODUCTION OF ENERGY RESOURCES BY MAJOR SOURCES IN TRILLIONS OF BTU[a] (1970-71)

Year	Anthracite	Bituminous coal and lignite	Natural gas, dry	Petroleum	Total Fossil fuels	Hydropower	Nuclear power	Total gross energy inputs	Percentage change from prior year
1970	247	15,001	24,154	19,772	59,174	2,630	229	62,033	+5.6
1971	221	13,933	24,871	19,559	58,584	2,833	391	61,808	+0.4

[a]Includes Alaska

TABLE E-14 PERCENTAGE CHANGE IN U.S. TOTAL PRODUCTION OF ENERGY RESOURCES BY MAJOR SOURCES (1970-71)

Year	Anthracite	Bituminous coal and lignite	Natural gas, dry	Petroleum	Total Fossil Fuels	Hydropower	Nuclear Power	Total gross energy inputs
1970	-7.2	+7.5	+5.8	+4.7	+5.8	-0.7	+56.8	+5.6
1971	-10.5	-7.1	+3.0	-1.1	-1.0	+7.7	+70.7	+0.4

TABLE E-15 DEMAND FOR ENERGY INPUTS IN ELECTRICAL SECTOR (1970-71)

Year	Coal[a]		Petroleum		Natural gas		Total Fossil fuels	Hydropower[b]		Nuclear		Energy Inputs Total
	Thousand Short tons	Trillion BTU	Million Barrels	Trillion BTU	Billion cubic feet	Trillion BTU	Trillion BTU	Million kWh	Trillion BTU	Million kWh	Trillion BTU	Trillion BTU
1970	322,357	7,483	333.8	2,087	3,894	4,015	13,585	252,571	2650	21,801	229	16,464
1971	331,633	7,698	386.9	2,417	4,000	4,124	14,239	269,580	2833	37,899	391	17,463

a) Includes anthracite, bituminous, and lignite coals.

b) Includes net imports and engligible amount of hydropower generated by industrial establishments.

E-16

TABLE E-16 DEMAND FOR ENERGY INPUTS TO INDUSTRIAL SECTOR IN TRILLIONS OF BTU (1970-71)

Year	Natural gas			Petroleum[a]			Coal[b]			Total Fossil Fuels	Electricity Purchased[c]	Total Fuel uses	Total Non-Fuel uses	Total Sector Inputs
	Fuel uses	Non-Fuel uses	Total	Fuel Uses	Non-Fuel uses	Total	Fuel uses	Non-Fuel uses	Total					
1970	9,475	687	10,162	3,252	2,015	5,267	4,853	151	5,004	20,433	2,210	19,790	2,853	22,643
1971	9,753	686	10,439	3,191	2,082	5,219	4,332	133	4,465	20,123	2,325	19,601	2,847	22,448

a) Petroleum products refined and processed from crude oil, including still gas, liquefied refinery gas and natural gas liquids.

b) Includes anthracite, bituminous, and lignite coals.

c) Utility electricity, generated and imported, distributed on basis of historical series in the Edison Electric Institute Yearbook. Conversion of electricity to energy equivalent was made at the value of contained energy corresponding to 100-percent efficiency using a theoretical rate of 3,412 BTU per kWh.

TABLE E-17 DEMAND FOR ENERGY INPUTS IN TRANSPORTATION SECTOR (1970-71)

Year	Coal[a]		Petroleum[b]		Natural gas		Total fossil fuels	Utility electricity purchased		Total energy input
	Thousand short tons	Trillion BTU	Million barrels	Trillion BTU	Million cubic feet	Trillion BTU	Trillion BTU	Billion kWH	Trillion BTU	Trillion BTU
1970	298	8	2,902.8	15,592	722,166	745	16,345	5	16	16,361
1971	250	7	3,004.9	16,139	800,000	825	16,971	5	17	16,988

a) Includes anthracite, bituminous, and lignite coals.

b) Includes bunkers and military transportation.

TABLE E-18 DEMAND FOR ENERGY INPUTS IN HOUSEHOLD AND COMMERCIAL SECTORS IN TRILLIONS OF BTU (1970-71)

Year	Natural gas	Petroleum[a]			Coal[b]	Total Fossil Fuels	Electricity Purchased[c]	Total Fuel Uses	Non-Energy Uses	Total Energy Inputs
		Fuel uses	Non-fuel uses	Total						
1970	7,108	5,371	1,082	6,453	427	13,988	3,000	15,906	1,082	16,988
1971	7,346	5,435	1,110	6,545	390	14,281	3,155	16,326	1,110	17,436

a) Petroleum products refined and processed from crude oil, including still gas, liquefied refinery gas and natural gas liquids.

b) Includes anthracite, bituminous and lignite coals.

c) Utility electricity, generated and imported, distributed on basis of historical series in the Edison Electric Institute Yearbook. Conversion of electricity to energy equivelent was made at the value of contained energy corresponding to 100-percent efficiency using a theoretical rate of 3,412 BTU per kWH.

TABLE E-19 ELECTRIC UTILITY INDUSTRY - INSTALLED GENERATING CAPACITY
[NET GENERATION AND THERMAL EQUIVALENT RESOURCE INPUTS (1971)]

Period	Installed Generating Capacity - MW	Load Factor	Net Generation Billion kWH	Heat Rate BTU/kWH	Energy Resource Inputs(Trillion BTU)
1971:					
Fuel burning plants[a]	302,810	.50	1,310	10,870	14,240
Nuclear plants[b]	8,687	.50	38	10,660	405
Hydropower plants[c]	55,898	.55	266	10,494	2,798
Total	367,395	.51	1,614	10,807	17,443

a) Fuel burning plants include steam, internal combustion, and gas turbine plants. Heat rate based on energy inputs to all fuel burning plants.

b) Energy input for nuclear power converted at an average heat rate based on AEC data for projected nuclear plant mixes.

c) Hydropower plants include hydro and pumped storage plants. Converted to theoretical energy inputs on the basis of national average heat rates for fossil-fueled steam-electric plants.

TABLE E-20 SECTORIAL DEMAND FOR COAL IN TRILLIONS OF BTU[a] (1970-71)

Year	Household and Commercial	Industrial			Transportation	Electrical Generation	Total Non Fuel uses	Total Fuel	Total
		Fuel uses	Non-fuel uses	Total					
1970	427	4,853	151	5,004	8	7,483	151	12,771	12,922
1971	390	4,332	133	4,465	7	7,698	133	12,427	12,560

a) Includes anthracite, bituminous and lignite coals.

TABLE E-21 SECTORIAL DEMAND FOR NATURAL GAS IN TRILLIONS OF BTU (1970-71)

Year	Household and Commercial	Industrial			Transportation	Electrical Generation	Total Non-energy uses	Total Fuel uses	Total
		Fuel Uses	Non-fuel uses	Total					
1970	7,108	9,475	687	10,162	744	4,015	687	21,342	22,029
1971	7,346	9,753	686	10,439	825	4,124	686	22,048	22,734

TABLE E-22 SECTORIAL DEMAND FOR PETROLEUM IN TRILLIONS OF BTU[a] (1970-71)

Year	Household and Commercial			Industrial			Transportation[b]	Electrical generation	Other not specified	Total non-fuel use	Total fuel use	Total input
	Fuel	Non-fuel use	Total	Fuel use	Non-fuel use	Total						
1970	5,371	1,082	6,453	3,252	2,015	5,267	15,592	2,087	215	3,097	26,517	29,614
1971	5,435	1,110	6,545	3,191	2,028	5,219	16,139	2,417	172	3,138	27,354	30,492

a) Petroleum products refined and processed from crude oil, including still gas, liquefied refinery gas and natural gas liquids.

b) Includes bunker fuel and military transportation.

TABLE E-23 DEMAND FOR FOSSIL FUELS FOR NON-ENERGY USES, BY SECTORS[a] IN TRILLIONS OF BTU (1970-71)

Year	Household and Commercial[b]	Industrial	Total
1970	1,082	2,853	3,935
1971	1,110	2,847	3,957

) No non-energy uses in transportation and electrical sectors.

) All non-energy uses for household and commercial sector supplied by petroleum

TABLE E-24 DEMAND FOR FOSSIL FUELS FOR NON-ENERGY USES BY SOURCE (1970-71)

	Bituminous coal and lignite[a]		Petroleum[b]		Natural gas		Total energy input
Year	(Thousand tons)	(Trillion BTU)	(Million barrels)	(Trillion BTU)	(Million cubic feet)	(Trillion BTU)	(Trillion BTU)
1970	5,610	151	578.0	3,097	665,884	687	3,935
1971	4,913	133	579.8	3,138	665,000	686	3,957

) Anthracite non-energy uses not included; negligible.

) Petroleum products refined and processed from crude oil including still gas, liquefied gas, and natural gas liquids.

TABLE E-23 DEMAND FOR FOSSIL FUELS FOR NON-ENERGY USES, BY SECTORS[a] IN TRILLIONS OF BTU (1970-71)

Year	Household and Commercial[b]	Industrial	Total
1970	1,082	2,853	3,935
1971	1,110	2,847	3,957

a) No non-energy uses in transportation and electrical sectors.

b) All non-energy uses for household and commercial sector supplied by petroleum

TABLE E-24 DEMAND FOR FOSSIL FUELS FOR NON-ENERGY USES BY SOURCE (1970-71)

Year	Bituminous coal and lignite[a]		Petroleum[b]		Natural gas		Total energy input
	(Thousand tons)	(Trillion BTU)	(Million barrels)	(Trillion BTU)	(Million cubic feet)	(Trillion BTU)	(Trillion BTU)
1970	5,610	151	578.0	3,097	665,884	687	3,935
1971	4,913	133	579.8	3,138	665,000	686	3,957

a) Anthracite non-energy uses not included; negligible.

b) Petroleum products refined and processed from crude oil including still gas, liquefied gas, and natural gas liquids.

TABLE E-25 ENERGY SOURCE AND CONSUMING SECTOR IN QUADRILLIONS OF BTU[a] (1971)

	Total	(Electricity)[d]	Residential	Commercial	Industrial	Trans-portation
Nuclear	0.4	(0.4)	(0.1)	(0.1)	(0.2)	-
Hydro	2.8	(2.8)	(0.9)	(0.7)	(1.2)	-
Coal						
Direct	4.9	-	-	0.4	4.5	-
Electricity	7.7	(7.7)	(2.5)	(1.9)	(3.3)	-
Natural Gas						
Direct[b]	18.6	-	4.2	3.2	10.4	0.8
Electricity	4.1	(4.1)	(1.4)	(1.0)	(1.7)	
Petroleum[c]						
Direct	28.0		3.5	2.6	5.7	16.2
Electricity	2.5	(2.5)	(0.8)	(0.6)	(1.1)	-
Total Gross Inputs	69.0	(17.5)	13.4	10.5	28.1	17.0
Conversion Losses	11.9		3.9	2.9	5.1	-
Net Consumption	57.1		9.5	7.6	23.0	17.0

a) [CEQ-74]

b) Imports were 0.9 quads

c) Imports were 8.3 quads

d) Figures in parentheses are gross inputs to electrical generation

E-1-2 BASIC AND CRITICAL MATERIALS

This section of Appendix E is intended to display the present situation in selected basic and possibly critical materials. Profiles of both metallic and non-metallic minerals are displayed in Tables E-26 through E-31; thus inclusion is based on the assumption that energy production relies in-part on products derived from these materials. The demand for these materials could become bottlenecks if their requirements for a given path are large compared to their total production.

TABLE E-26 IRON ORE, IRON AND FERRO ALLOYS - PROFILE 1971[a]

Production	
Domestic Ore	80,762 x 10^3 Long Tons
Foreign Ore	40,124 x 10^3 Long Tons
Exports	3,061 x 10^3 Long Tons
Blast Furnace Production	
Pig Iron	91,435 x 10^3 Long Tons
Ferro Alloys	381 x 10^3 Long Tons
Electric Furnace	
Ferro Alloy	2,035 x 10^3 Long Tons
TOTAL	93,470 x 10^3 Long Tons

a) [DOC-73]

TABLE E-27 BAUXITE AND ALUMINUM - 1971[a]

Bauxite Ore	
Domestic Production	2,419 x 10^3 Long Tons
Imports	12,326 x 10^3 Long Tons
Exports	34 x 10^3 Long Tons
Primary Aluminum	3,925 x 10^3 Long Tons
Secondary Aluminum	814 x 10^3 Long Tons
Imports	690 x 10^3 Long Tons
Exports	293 x 10^3 Long Tons
Total Consumption	5,046 x 10^3 Long Tons

a) [DOC-73]

TABLE E-28 CEMENT PROFILE 1971[a]

Production	
Portland	77.008×10^6 tons
Masonry	3.309×10^6 tons
Imports	3.087×10^6 tons
Exports	$.125 \times 10^6$ tons
Stock at Mill (year end 71)	6.116×10^6 tons

a) [DOC-73]

TABLE E-29 COPPER PROFILE 1971[a]

Production, Refined	
Domestic Ore	$1,411 \times 10^3$ Tons
Foreign Ore	181×10^3 Tons
Total New Refined	$1,592 \times 10^3$ Tons
Secondary Production	$1,200 \times 10^3$ Tons
Imports	523×10^3 Tons

a) [DOC-73]

TABLE E-30 MOLYBDENUM, TUNGSTEN AND ZINC PROFILE 1971[a]

Molybdenum:	
Production	54,796 tons
Imports	23,142 tons 427 tons
Exports	427 tons
Consumption	33,200 tons
Tungsten:	
Production	3450 tons
Imports	289 tons
Consumption	5,811 tons
Stocks	1,760 tons
Zinc:	
Production	
Domestic Ore	$2,104 \times 10^3$ Tons
Foreign Ore	362×10^3 Tons
Secondary Production	81×10^3 Tons

a) [DOC-73]

TABLE E-31 PROFILE TIN, NICKEL, LEAD 1971[a]

Tin: 1971	
Production: Secondary	20,096 Long Tons
Imports	
Metal	46,940 Long Tons
Ore (tin content)	3,060 Long Tons
Consumption	69,950 Long Tons
Nickel: 1971	
Production	
Primary	15,654 Short Tons
Secondary	29,657 Short Tons
Imports: Ore (nickel content)	142,183 Short Tons
Consumption	128,816 Short Tons
Stocks	16,105 Short Tons
Lead: 1971	
Production-Refined	
Domestic Ore	573×10^3 Short Tons
Foreign Ore	77×10^3
Secondary Refined	597 Short Tons
Imports	199 Short Tons
Exports	6 Short Tons
Consumption	1,432 Short Tons

a) [DOC-73]

E-1-3 MANPOWER: THE PRESENT

Total Labor Force [DOL-73]

The available work force in the period 1975-2000 is already determined to a great extent, particularly until 1990. The 1990 labor force pool, persons 16 years and older, is in the present population. The total work force pool for 1990 to 2000 can be estimated from birth projections for the years 1974-1985. The birth rate has been changing rapidly in the last few years. The rate has dropped from the Census Bureau series C projections (2.8 children per woman) to below series E (2.1 children per woman). At this point (mid 1974) the rate is estimated to be below the replacement rate approaching the series F projections (1.8 children per woman).

Table E-32 displays the total population and total available labor pool. The labor pool is shown for two age intervals: 16 and over, and 24 and over. The second interval is listed since it excludes most students and military. The age group of 24 and over represents persons involved in jobs with some experience or educational background. Figures E-1, E-2 display the trends of the population and labor pool totals. The total labor pool grows 40 percent over the thirty years 1970 to 2000 while the total population grows 29 percent. The female labor pool is and remains larger than the male by about 6 or 7 million.

Table E-33 displays the estimates of the actual work force total, male and female. It should be noticed that the percent of males employed goes through a minimum in 1980 while the percent of females employed expands rapidly in the period 1970-1980.

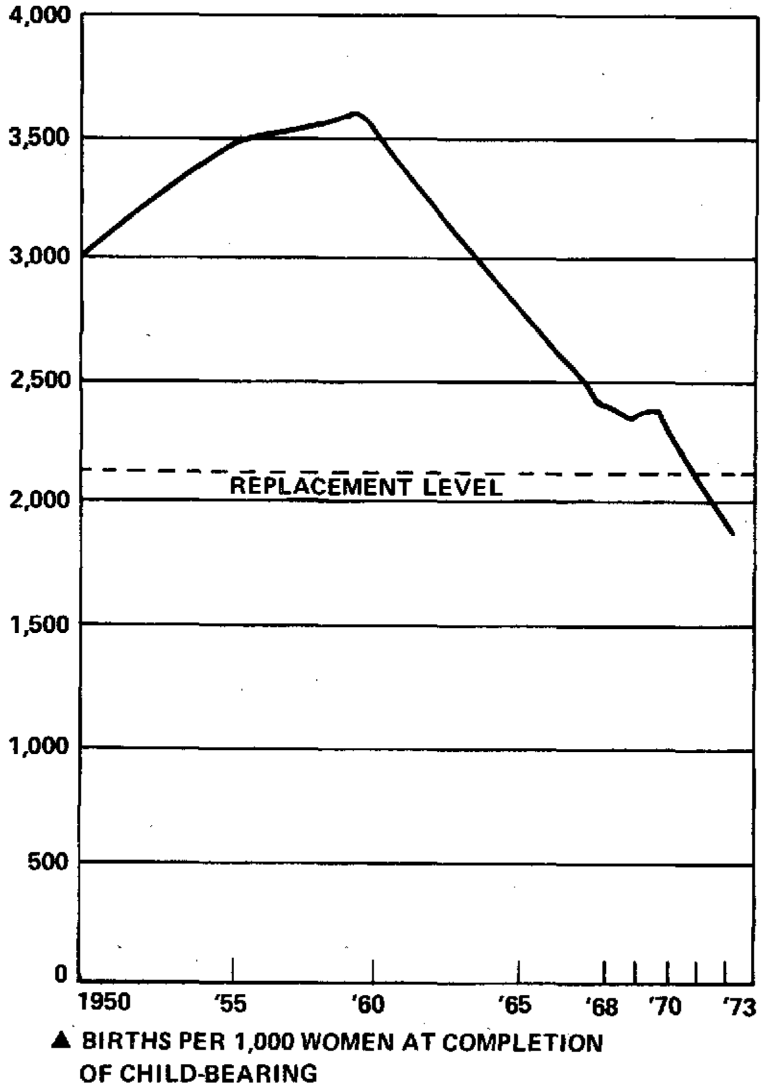
Another observation from the Census Bureau data is that the age group 55 to 59 and 60 to 64 and 65 and over show significant decreases in the percent of persons employed for men. The intervals for women of the same ages shows considerable expansion of the percentage of persons employed. The percent and number of non-participating individuals is shown in Table E-34 for the years 1970 and 1990. For men the percent of non-participation increases as does the overall number. For women the percent of non-participation declines bet the number increases greatly. This reflects the greater increase in the women over 65 age interval from 11.4 million in 1970 to 16.7 million in 1990.

TABLE E-32 POPULATION AND LABOR FORCE SERIES E PROJECTIONS[a]

All Figures are Millions Unless Noted

	Total Population	Labor Pool 16 and older	Labor Pool 24 and older	Male Labor Force 16 and over	Female Labor Force 16 and over
1970	205	142	111	68.6	73.7
1980	224	167	130	80.3	87.1
1990	247	183	151	87.9	95.2
2000	264	199[b]	169[b]	96[b]	103[b]

a) DOL - 73
b) Extrapolated



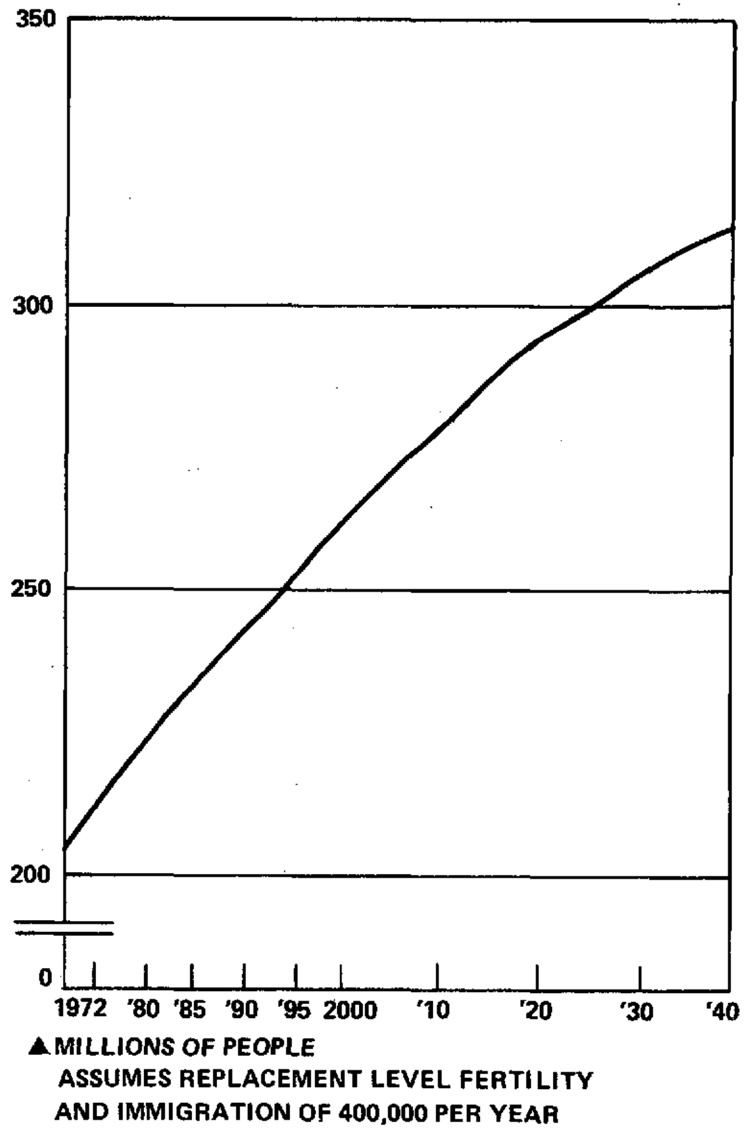


FIGURE E-1 RECENT HISTORY OF BIRTH RATE AND U.S. POPULATION PROJECTIONS ASSUMING BIRTHS EQUAL REPLACEMENT [BUS. WK.-73]

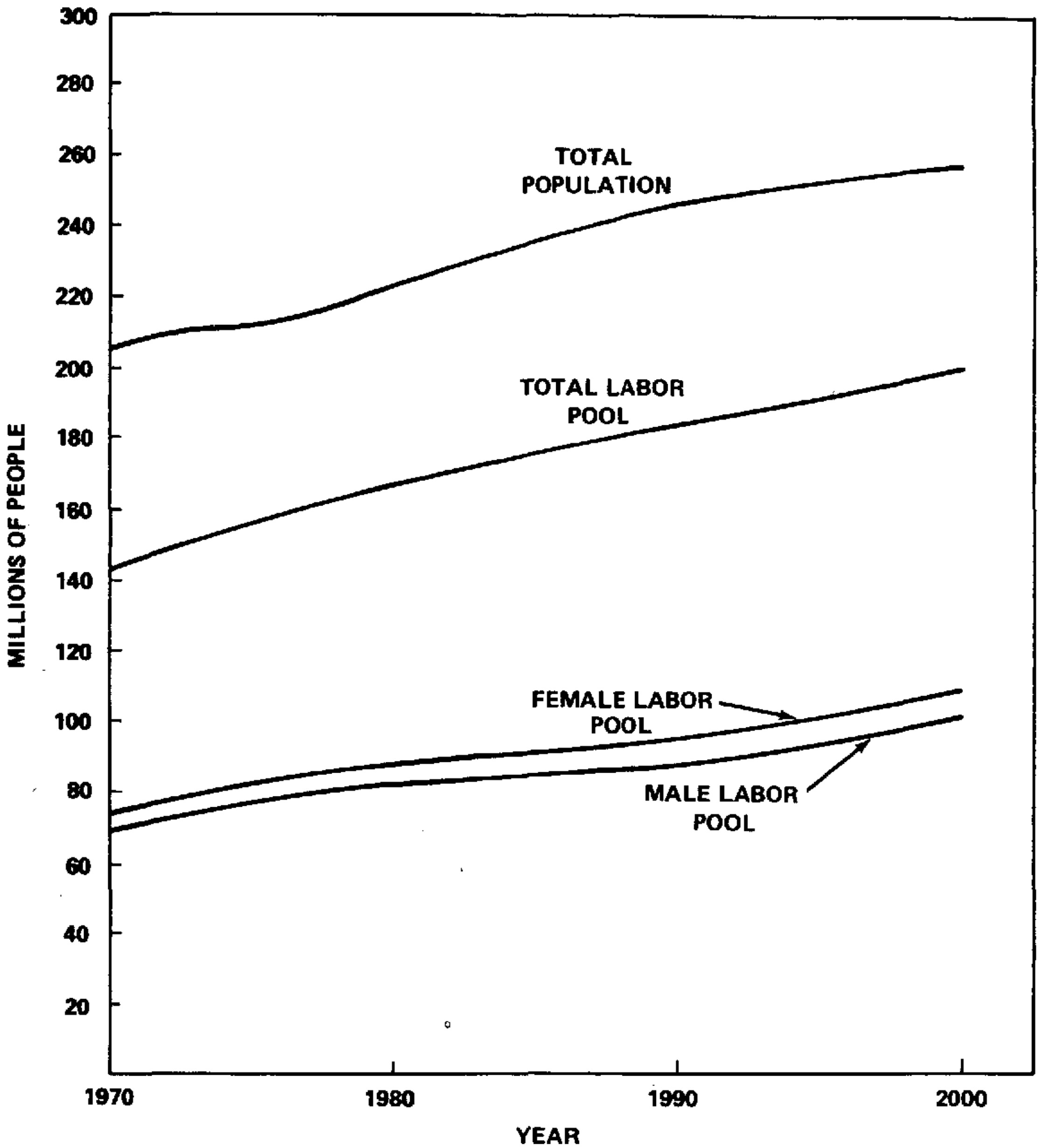


FIGURE E-2 U.S. POPULATION TO 2000 BASED ON CENSUS BUREAU DATA TO 1990 AND EXTRAPOLATED FROM 1974-1984 BIRTH RATES

TABLE E-33 LABOR FORCE PARTICIPATION (16 AND OVER)[a] IN MILLIONS

NET IS NUMBER ACTUALLY EMPLOYED

		Gross	%	Net
Total	1970	142	60.3	88.2
	1980	167	60.8	102
	1990	183	61.5	112
	2000	199[b]	62.2[b]	124[b]
Male	1970	68.6	79.2	54.3
	1980	80.3	78.0	62.6
	1990	87.9	78.4	68.9
	2000	96[b]	79[b]	75.8[b]
Female	1970	73.7	42.8	31.5
	1980	87.1	45.0	39.2
	1990	95.2	45.9	43.7
	2000	103[b]	47[b]	48.4[b]

a) [DOL - 73]
b) Extrapolated

TABLE E-34 CHANGES IN PARTICIPATION PERCENTAGES FROM 1970 TO 1990

MEN Non-participating in millions

Age Group	1970 %	1970 Number	1990 %	1990 Number
55 to 59	12	0.6	14	0.7
60 to 64	26	1.0	31	1.4
65 and over	74	6.2	81	8.9
Total		7.8		11.0

WOMEN Non-participating in millions

Age Group	1970 %	1970 Number	1990 %	1990 Number
55 to 59	52	2.6	47	2.6
60 to 64	64	2.9	61	2.4
65 and over	81	11.4	82	15.3
Total		16.9		20.3

Present State of Engineering Manpower

The following information summarizes the present state of engineering manpower. This information was abstracted from the sources listed in Table E-35.

TABLE E-35 ENGINEERING MANPOWER

Engineers Employed in Private Industry 1970[a]	856,700.
Engineers Employed in the Federal Govt. 1970[a]	82,972.
Total Engineering Employment 1970[b]	1,100,000.
Total Engineering Employment 1974[b]	1,167,000.
Unemployment Rate for Engineers 1971[a]	3.0%
Unemployment Rate for Engineers 1974[b]	1.4%
Engineers Employed in Universities and Colleges 1971[a]	27,130.
Engineers Employed in Chemical & Allied Prod. Industry 1970[a]	46,400.
Engineers Employed in Petroleum Refining Industry 1970[a]	9,200.
Engineers Employed in Mining Industry 1970[a]	17,800.
Engineers Employed in Contract Construction Industry 1970[a]	50,300.
Engineers Employed in Transportation, Public Utilities & other non-manufacturing Industries 1970[a]	81,900.
New B. S. Engineers Graduated in 1972[b]	44,190.
New B. S. Engineers Graduated in 1973[b]	43,429.
Freshman Engineering Enrollment 1973[b]	32,179.
Engineers Admitted to the U. S. as Immigrants 1971[a]	9,015.
Engineers Admitted to the U. S. as Immigrants 1972[a]	7,436.

a) [DOC-73]

b) [Alden-74]

Production Workers: Percent Status

Tables E-36, E-37, and E-38 list the employment of production workers by various SIC codes for industries closely related to the energy industry.

TABLE E-36 PRODUCTION WORKERS IN CONSTRUCTION, 1971[a]

	Total	Female	Construction
Total Contract	$3.3x10^6$	$17x10^4$	$2.8x10^6$
General Building Contractors SIC 15[b]	$94\ x10^4$	$47x10^3$	$78\ x10^4$
Heavy Construction Contractors SIC 16	$71\ x10^4$	$28x10^3$	$61\ x10^4$
Special Trade Contractors	$1.6x10^6$	$92x10^3$	$1.3x10^6$

a) DOL - 72

b) SIC codes are The Standard Industrial Classification of the Department of Commerce

TABLE E-37 PRODUCTION WORKERS IN MANUFACTURING, 1971[a]
(In Thousands)

	Total	Female	Production
Total Non-Agricultural	71,000	26,000	45,000
Private Sector	58,000	21,000	48,000
Primary Metals SIC 33	1,300	88	1,000
Blast Furnace and Basic Steel SIC 331	630	27	500
Iron and Steel Foundries SIC 332	210	10	180
Non-ferrous SIC 333,4	87	4	68
Al SIC 3334	31	.8	25
Non-ferrous Rolling and Drawing SIC 335	210	31	150
Cu SIC 3351	42	3	31
Al SIC 3352	69	7	51
Structural Metals Fabrication SIC 344	410	43	290
Steel SIC 3441	100	6	79
Turbines, Engines SIC 351	120	16	80
Regrigeration Machinery SIC 3585	92	13	64
Concrete, gypsum, plaster SIC 327	190	11	150
Coment, hydraulic SIC 324	32	1	25

a) DOL-72

TABLE E-38 PRODUCTION WORKERS IN MINING, 1967

	Establishments	Total Employees In Thousands	Production Workers In Thousands
Total	28,579	567	433
Metals	1,155	71	55
Iron	146	23	18
Copper	156	21	15
Lead	104	4	3
Zinc	63	5	4
Bauxite	17	1	1
Coal	4,484	131	115
Anthracite	403	6	6
Bituminous	3,921	123	107
Lignite	45	1	1.5
Oil & Gas Extraction	16,358	245	167
Crude Petro	7,278	107	55
Gas	1,518	20	11
Drilling	2,347	43	39
Exploring	636	8	7
Non-metals	6,582	120	95
Stone, sand Gravel, Clay	5,865	89	74
Chemicals, Fertilizers	233	24	16

a) U.S. Census-67

E-2 IMPROVEMENT OF FUEL EFFICIENCY IN END USE

Improved Fuel Management

A study for the Energy Policy Project [Ford-74] by the Thermoelectron Corporation [Lazarides-74] reports that a third of the fuel consumed industrially may be saved by the use of known technologies and an energy conservation ethic. Industry uses fuel for the following processes:

Process Steam	Electric Drive	Electrolysis	Direct Heat	Feedstock	Other
40%	19%	3%	28%	9%	1%

Improved fuel management would combine some of these operations. Consider the consumption of fuel in a boiler to generate process steam and the consumption of fuel for direct heat. Using a gas turbine to burn the fuel would generate by-product electricity. Process steam could be generated from the exhaust heat. Alternatively steam might be generated at a higher temperature and pressure and fed into a steam turbine to generate the electricity before using the steam in process. When a cycle to improve use of fuel is added at the fuel-heat interface it is termed a "topping" cycle. Improved use of exhaust heat near the heat-atmosphere interface are called "bottoming" cycles. Exhaust heat can be utilized with recuperators (a heat exchanger in the exhaust gas to preheat the combustion air), regenerators (refractory matter that stores the heat over which combustion air can be directed), and low temperature heat engines or heat pumps (the organic Rankine engine is given special mention by Lazarides).

The Thermoelectron report [Lazarides-74] emphasizes the free energy difference between initial and final states of a process (compared at the same temperature pressure), the available useful work, as a yardstick to measure the theoretical limit on work output. This yardstick is used to suggest new processes, recycling potentials, and the need for new technology. Table E-39 summarizes Thermoelectron's analysis of about 40 percent of the industrial sector.

Heat Pumps

Because of their ability to produce heating and cooling with a high coefficient of performance (1.50-2.50), heat pumps represent an excellent energy saving substitute for residential and commercial heating and cooling requirements. The actual overall efficiency of a heat pump system depends on the local climate. Dunning and Geary [Dunning-74] have shown that one unit of work output in Pittsburgh requires 1.6 units of input for a heat pump system compared with 2.2 in for a gas furnace system. Table E-40 compares the heat pump to conventional heating and cooling systems.

TABLE E-39 IMPROVEMENT OF FUEL EFFICIENCY

Industry	Output, 68 10^6 tons/yr.	Total Fuel Consumed, 1968 Sector	Total Fuel Consumed, 1968 Quads	Theoretical Savings Limit, Quads	Projected Savings from Known Tech. Quads: Total	Steam Turbines[a]	Heat Transfer[b]	Process Imp'ts.	Amount Recycled, % Feedstock
Iron & Steel	131	15.2	3.5	2.7	1.2	.4	.2	.6	28% now, recycled autos excluded, 0.2 quads saving feasible[c]
Petroleum Refinery	590	11.4	2.6	2.2	.6	.25	.12	.23	------
Paper & Paperboard	50	5.4	2.0	2.0	.8	---	---	.8[d]	5% now . . . 30% feasible saving .4 quad
Aluminum	3.88	2.8	.63	.54	.2	---	---	.2	4% now . . . 33% possible saving .2 quad
Copper	3.1	.4	.08	---	.03	---	.015	.015	19% now, no saving possible
Cement	72	2.5	.57	.55	.25	---	.08	.17	

a) Lazarides estimates that all of the purchased electricity by industry of 5.6 quads could be generated by industry and that the industrial sector could export 4 quads of electricity (federal regulations allowing) if large and small industries are included.

b) Just preheating combustion air using exhaust heat is estimated to save 1.6 quad if applied industry wide.

c) OEP-72

d) Included is waste pulp and wood bark for fuel. The paper industry has the capacity to generate excess electricity at 585 KWH/ton of output which equals a continuous power level of 3330 megawatts (59.4 megawatts for a 1000 ton/day paper mill).

TABLE E-40 COSTS OF EQUIVALENT COMFORT-CONDITIONING SYSTEMS FOR AN 1850 SQ. FT. HOUSE[a]

	EQUIPMENT AND INSTALLATION COST	ANNUAL CAPITAL COST[b]	ANNUAL MAINTENANCE[c]	TOTAL ANNUAL FIXED COST
Heat Pump	$ 1,800	$ 153	$ 42	$ 195
Gas Furnace with Electric Air Conditioning and Furnace Flue	1,550	132	42	174
Oil Furnace and Storage Tank with Electric Air Conditioning and Furnace Flue	2,050	173	48	221

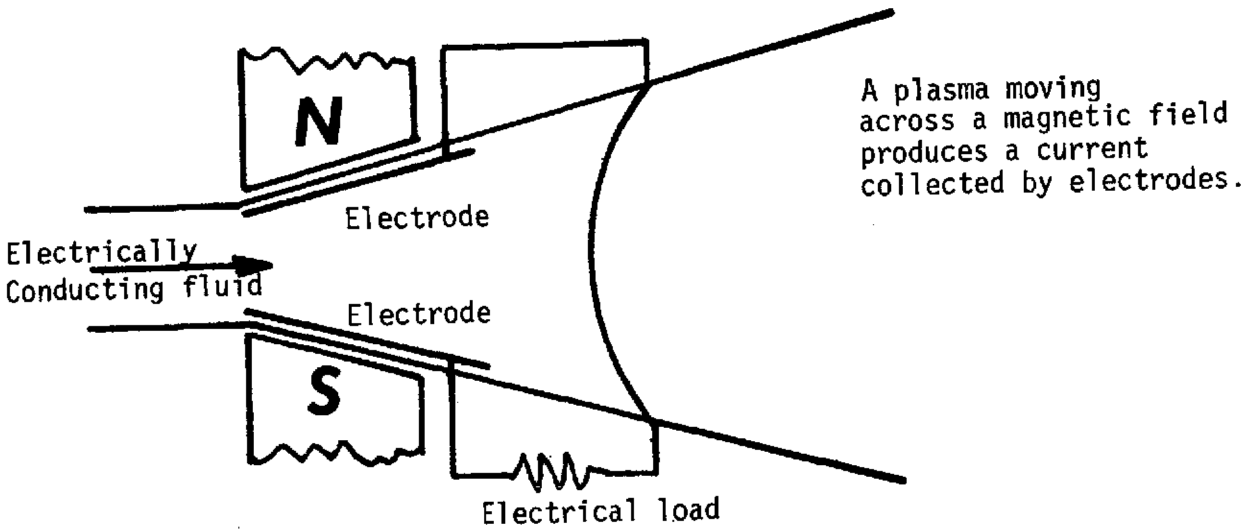
a) [Dunning-74]

b) Capital cost based on 25 year mortgage at 7%

c) Cost of an annual maintenance contract

New Techniques

Magnetohydrodynamics is an especially exciting topping cycle system for fossil fuel generation of electricity [Dicks-74]. Electrode materials limit continuous time of operation at present. Fuel plus potassium seed and preheated ait at 2700°K produces a plasma that flows through a magnetic field. The deflected ions in the fluid produce an electric current for load that is collected by electrodes. The hot gas continues into a boiler to fuel a steam plant.



Conversion efficiency may reach 50 percent with an MHD topping cycle compared to about 35 percent with conventional external combustion systems. This method is being investigated using pulverized coal, natural gas, and liquid fuels.

Solar heating can be combined with Diesel engine-compressors to raise process steam. Of the 10.6 quads used by process steam in 1968 in industry, 7 quads could have been saved this way [Lazarides-74]. The breakeven point is $1.45/10⁶ BTU which is double the present average fuel cost. This cost includes the standby system. The 7 quads should be reduced by the ratio of sun time/use time until suitable storage materials are developed.

Fuel cells also hold promise for eventual use in homes, small industries, and/or integrated utilities.

Electric Cars

The NEE [Ross-73, 73-1] predicts 5 x 10^6 electric cars by 1985 and 100 x 10^6 electric cars by 2000. The FTFB does not consider the use of electric cars. Westinghouse proposes the Ni-An (or Ni-Fe) battery for pre-1985 and the Zn-air [Dunning-74-1] or Fe-air [Brown-74] battery for post-1985. Cell reactions are [Hottel-71]:

$$2\ NiO(OH) + 2H_2O \longrightarrow 2\ Ni(OH)_2 + Zn(OH)_2$$

$$2\ Zn + O_2 + 2H\ O \xrightarrow[30\%\ KOH]{} 2\ Zn(OH)_2$$

$$2\ Fe + O_2 + 2H_2O \xrightarrow[30\%\ KOH]{} 2\ Fe(OH)_2$$

Table E-41 makes some comparisons on a per car basis [Stuhlinger-74].

Batteries would consist of about 100 cells of 1.1 v. each [Oswin-67]. Assuming we want to put 20 KWH back in upon charging requires

	120 v. Charge	240 v. Charge
8 hr. Charge	25 amp.	12.5 amp.
4 hr. Charge	50 amp.	25 amp.

Overall material needs are listed in Table E-42.

Transportation

Figures E-3 to E-9 illustrates how the transportation sector is increasingly dependent on the most inefficient modes - air and the automobile. By the year 2000 aircraft and automobiles are projected to consume 29 quad of fuel if current trends continue [OEP-72]. Governmental policy favors development of air and highway transport. It subsidizes short air flights by regulation of rate structures and encourages highway construction by providing matching money. Governmental policy has also mandated emission controls which have caused increases in fuel consumption.

Data on transportation is summarized in Figures E-3 to E-9.

Residential

Data on household electrical consumption is given in Table E-43.

TABLE E-41 A COMPARISON OF ALTERNATIVE BATTERIES FOR COMMUTER CARS

	Pb-Acid	Ni-Zn	Zn-air[c]
lbs of battery	1650	1650	211[a]
Kg of battery	750	750	96
KWH (1/2 KWH/mi)	30	30	60[b]
KWH/kg	.04	.04	.35
WH/lb	18	18	175

a) Battery weight is assumed to be made up of 1 part Zn: .8 part KOH solution or water: .2 part other materials (casing, etc.) [Oswin-67]

b) With this battery system enough energy can be stored to provide a 40 mile range at 1/3 discharge. This eliminates charging at both ends of a commuter trip.

c) Controversy exists about whether Zn-air or Fe-air will win out commercially. The Fe-air has o.11 KWH/Kg [Brown-74] but it can be discharged 100% and recharged (after 1000 cycles capacity is 80%). The Fe-air battery would weigh about the same as the Zn-air battery for this application.

TABLE E-42 PROJECTED MATERIAL NEEDS FOR ELECTRIC CARS

		1972	1985	2000
Electric Cars		0	5×10^6	100×10^6
Total Cars		97×10^6	133×10^6	167×10^6
Extra Gigawatts				110 [Ross-73]
Extra Quads Consumed			.1	2.2 [Trumbower-74]
Mass of Zn and Ni, lbs			4×10^9	1.1×10^{10} a
tons			2×10^6	5×10^6 a
Mass of Cu for Charging Cables, ton				2×10^4 b
Production in 1971, ton:	Zn			1×10^6
	Ni			2×10^5
	Cu			2×10^6
	Fe			125×10^6

a) Vans and trucks might increase this figure by 50 percent.

b) Assuming 1/8 inch Cu wire, 3 strand cable, and 24 ft/car of cable leads to 9×10^8 ft of wire = 7×10^4 ft^3 = 2×10^4 ton. Materials needs for the rectifier needed to convert a.c. to d.c. to charge the battery are not known, however, battery chargers are standard shelf items.

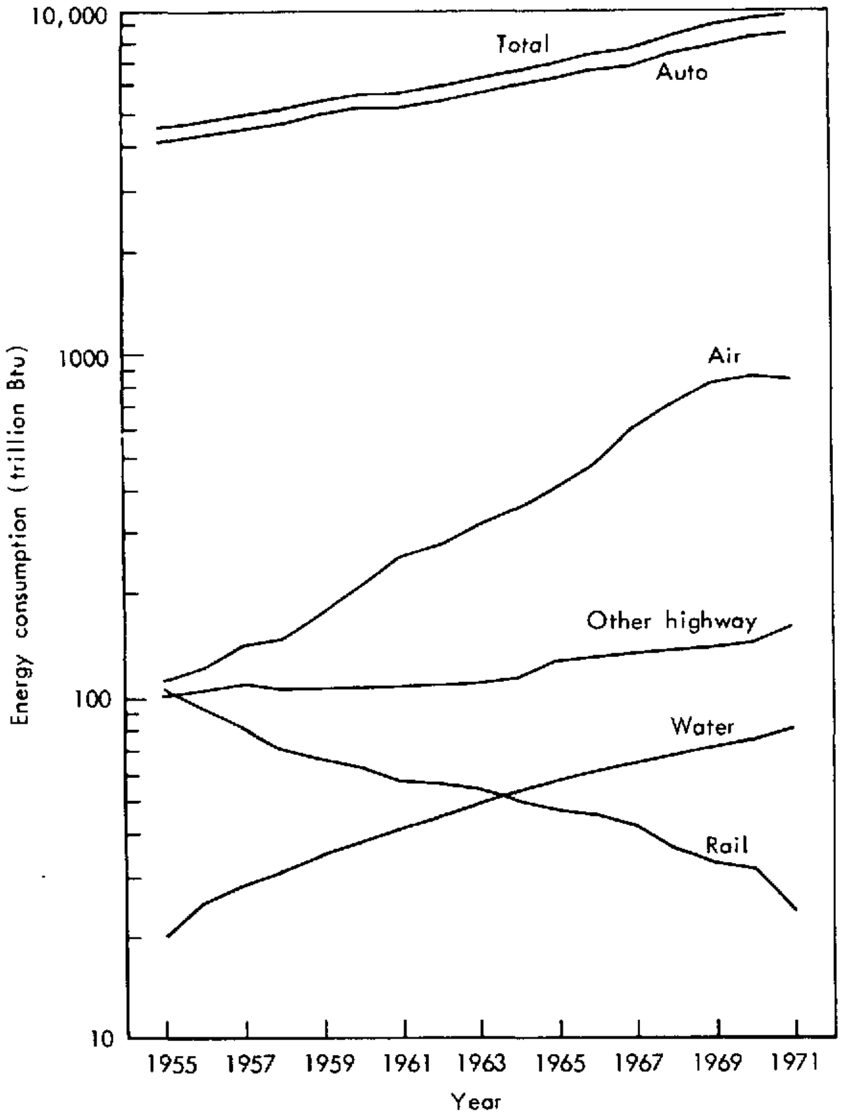


FIGURE E-3 DOMESTIC PASSENGER TRANSPORT ENERGY CONSUMPTION BY MODE, 1955-1971 [RAND-73-1]

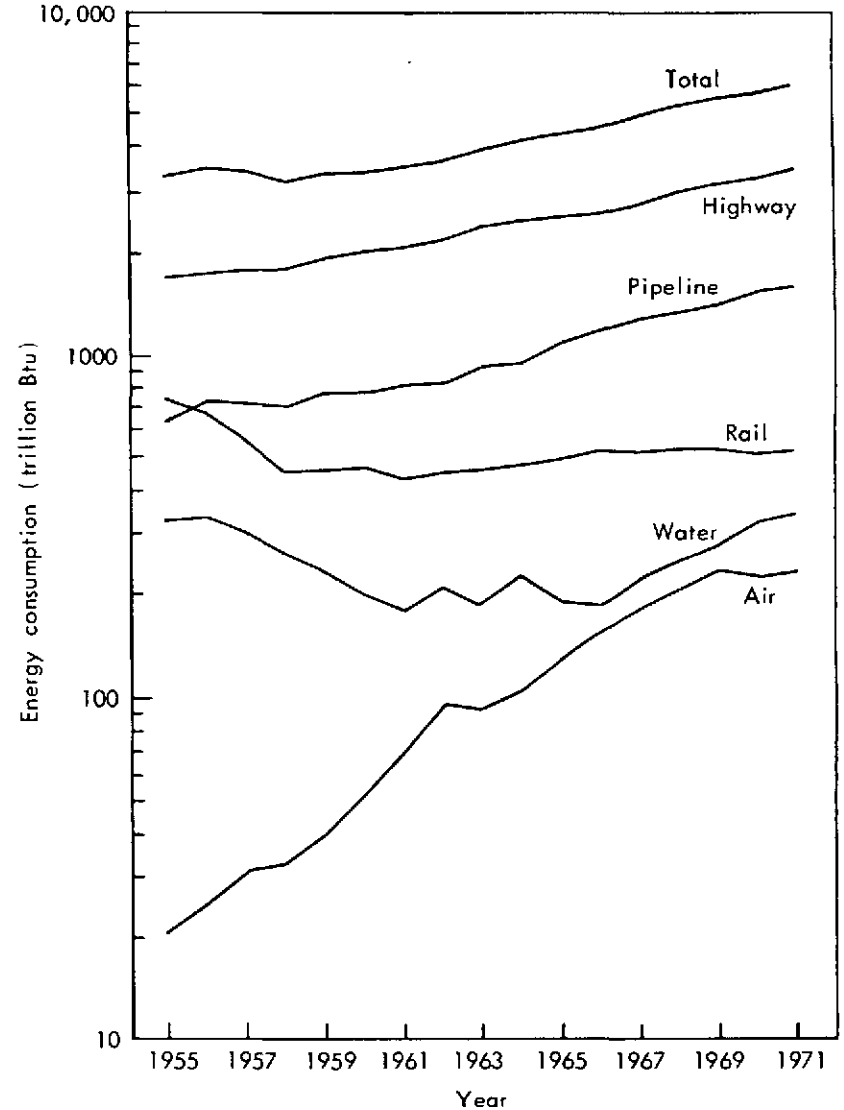
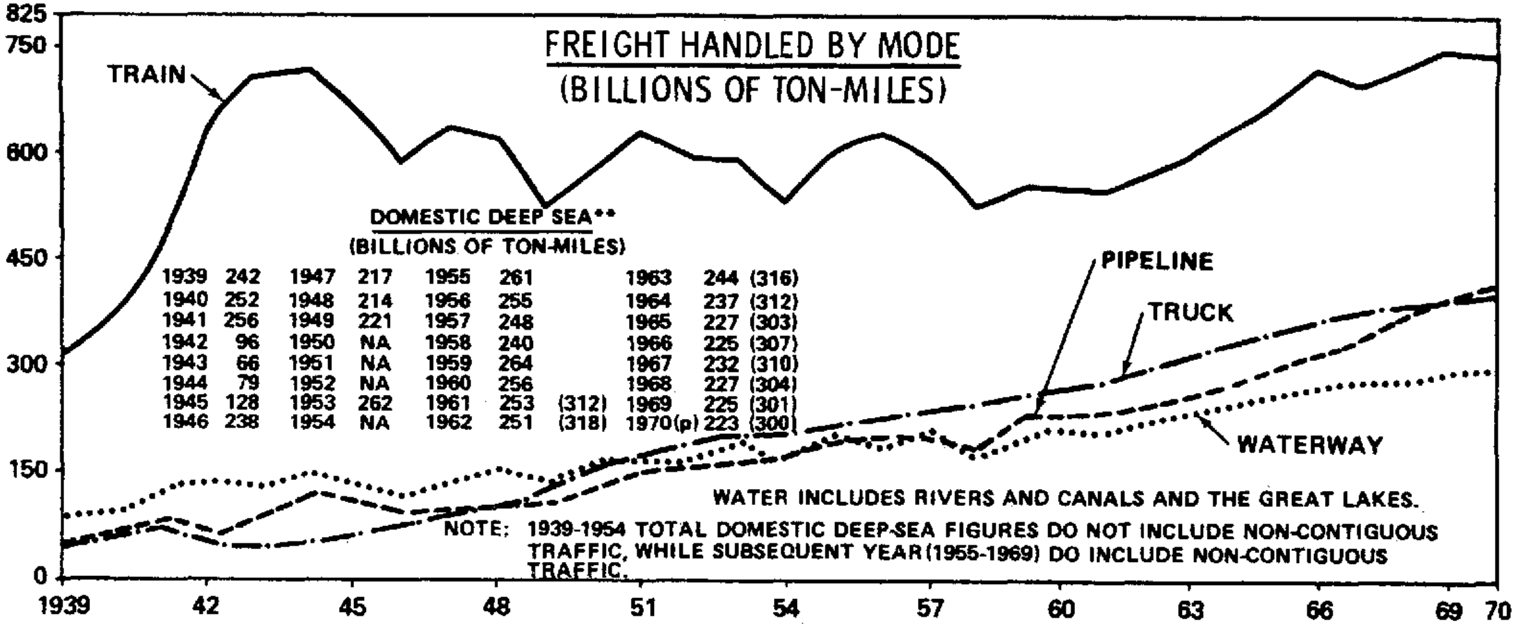


FIGURE E-4 DOMESTIC FREIGHT TRANSPORT ENERGY CONSUMPTION BY MODE, 1955-1971 [RAND-73-1]



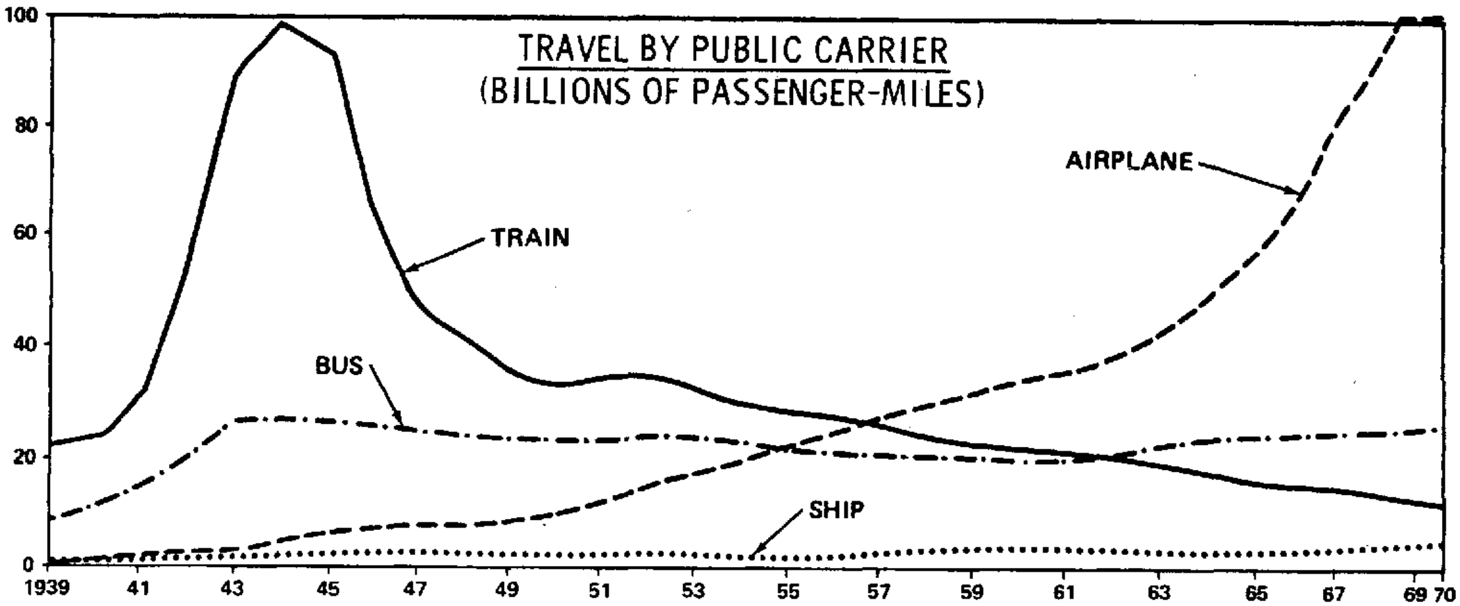


FIGURE E-5 TRENDS IN INTERCITY PASSENGER AND FREIGHT MOVEMENT [OEP-72]

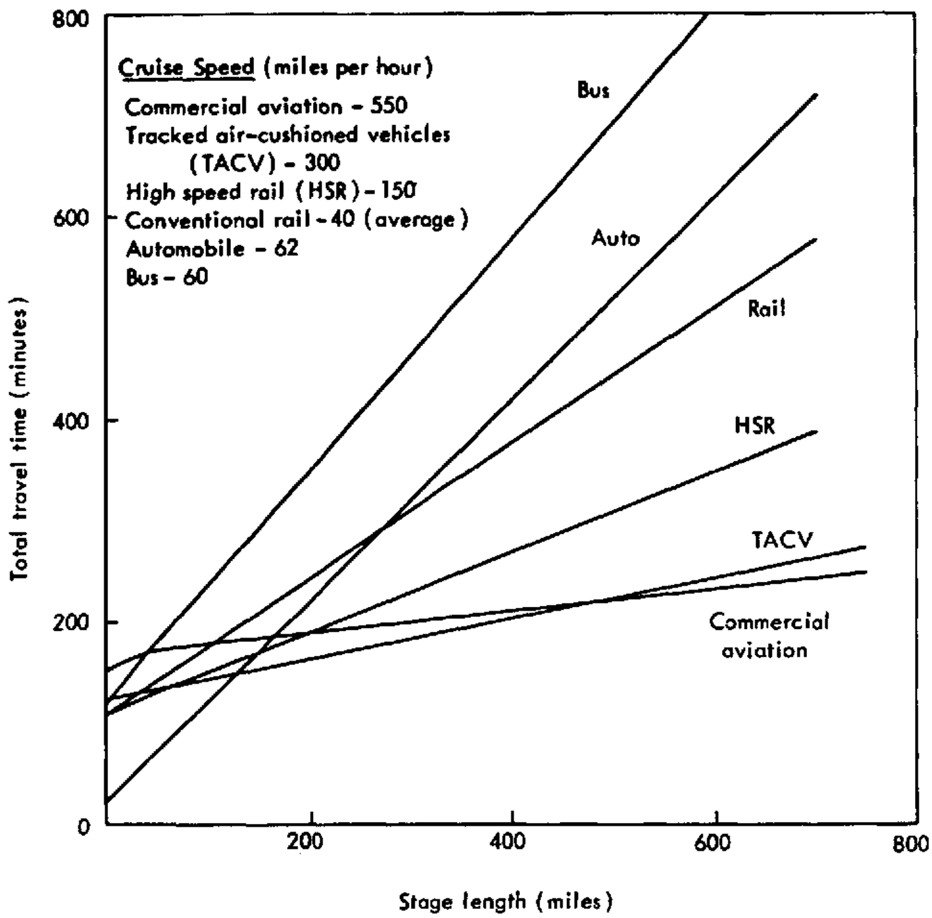


FIGURE E-6 DOOR-TO-DOOR TRAVEL TIMES FOR SEVERAL MODES. [RAND-73-2]

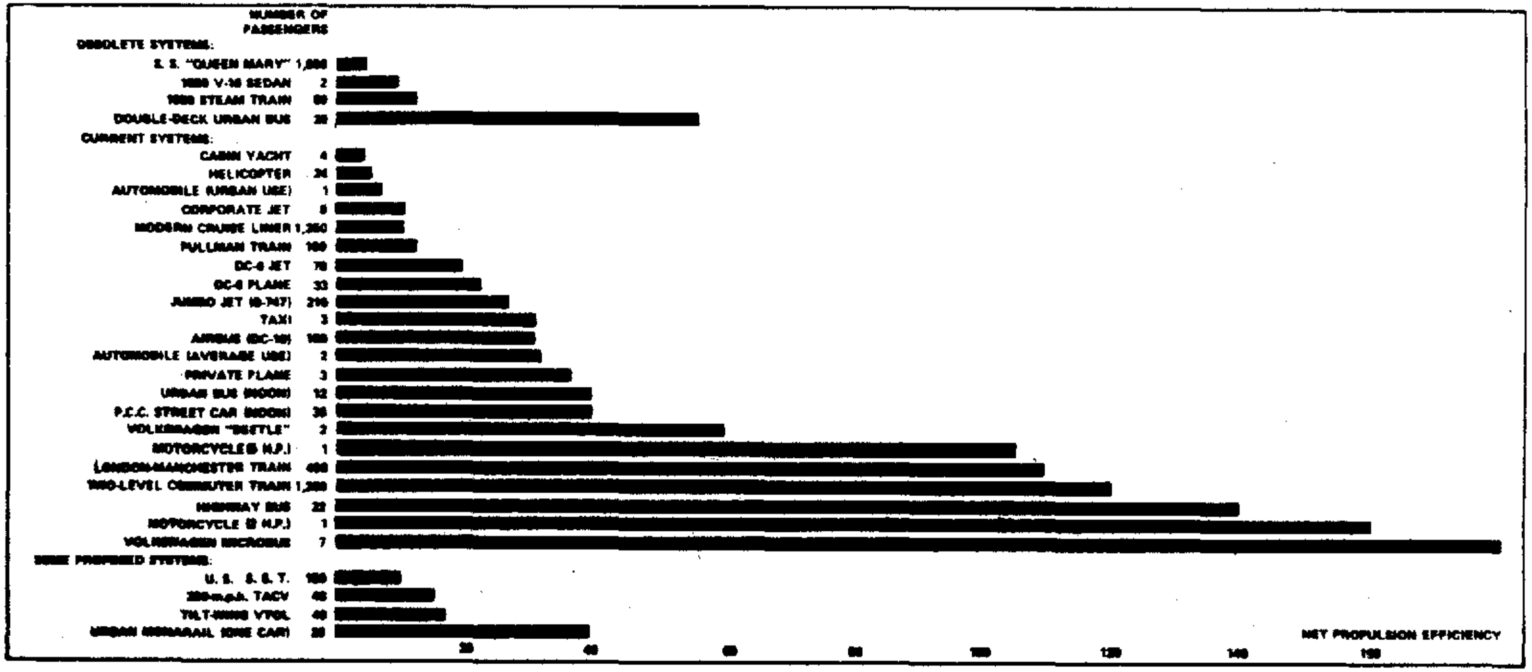


FIGURE E-7 ALL OF THE PRINCIPAL SYSTEM ALTERNATIVES FOR PASSENGER TRANSPORTATION FOR WHICH DATA ARE READILY AVAILABLE ARE COMPARED IN THIS CHART IN TERMS OF THEIR NET PROPULSION EFFICIENCY, THE NUMBER OF PASSENGER-MILES MOVED PER GALLON OF FUEL. NOTE THE NUMBER OF PASSENGERS ON WHICH THE EFFICIENCY IS CALCULATED IS NOT NECESSARILY A MAXIMUM CAPACITY BUT IS INSTEAD AN AVERAGE FIGURE FOR PRESENT EXPERIENCE. EFFICIENCY RISES DRAMATICALLY AS MORE PASSENGERS ARE ACCOMMODATED, WITH THREE OCCUPANTS A VOLKSWAGEN "BEETLE" COMES OUT WITH A NET PROPULSION EFFICIENCY OF 100. [OEP-72]

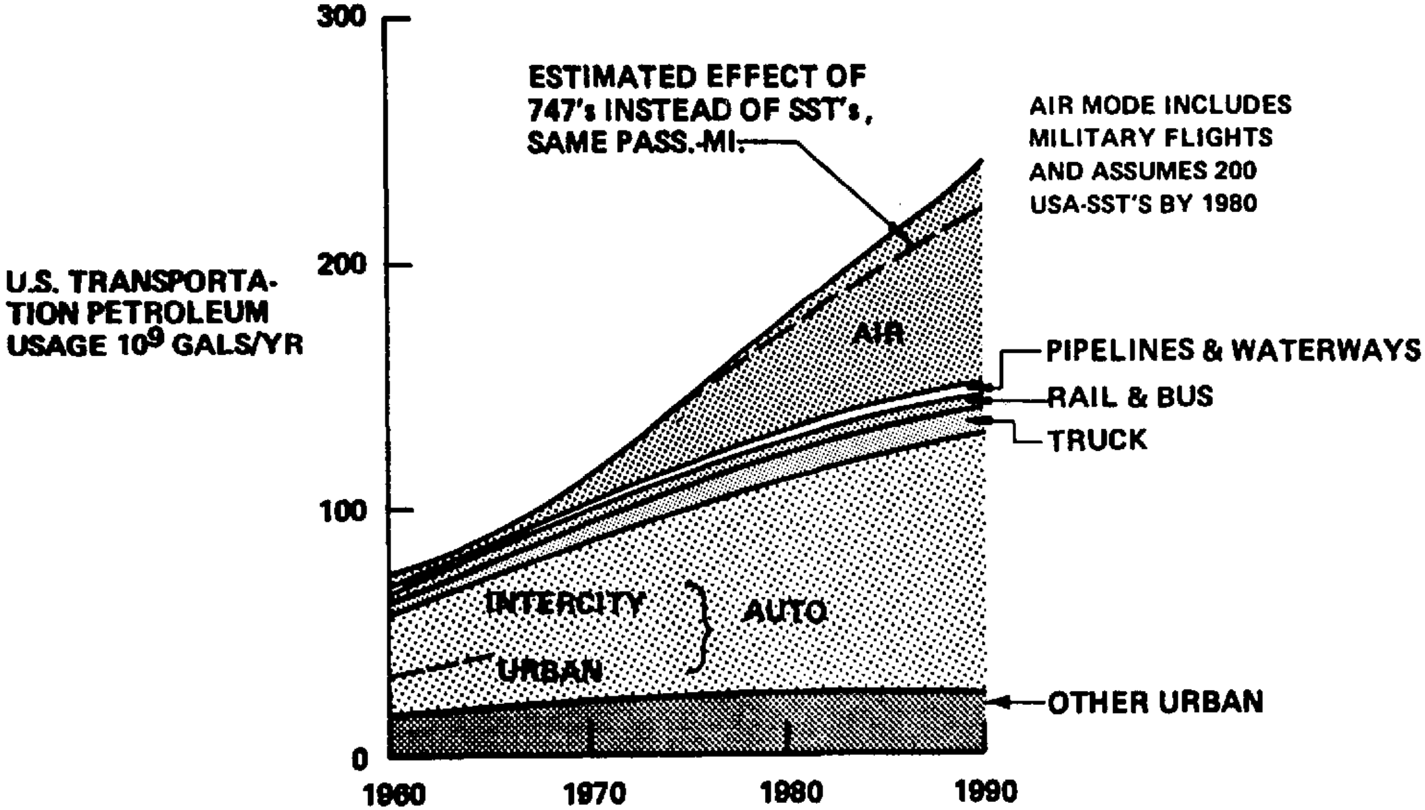
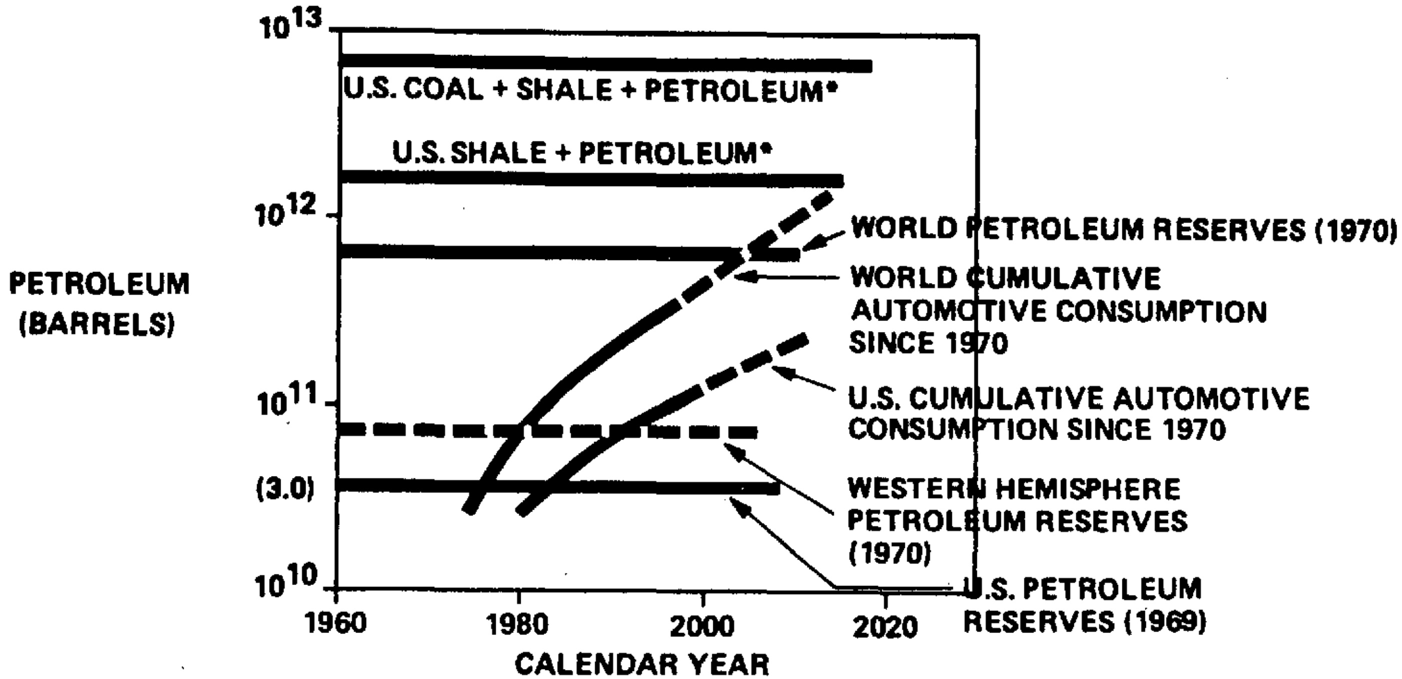


FIGURE E-8 U. S. TRANSPORTATION ENERGY BY MODE [OEP-72]



VEHICLE POPULATION RATE OF INCREASE
WORLD – 6.8%
U. S. – 4.0%
CONSUMPTION – 19.1 bbl/YR

FIGURE E-9 PRESSURE ON PETROLEUM RESERVES FROM AUTOMOTIVE TRANSPORTATION [OEP-72]

TABLE E-43 ESTIMATED AVERAGE ANNUAL ENERGY CONSUMPTION OF ELECTRIC HOUSEHOLD APPLIANCES, 1969[a]

Kitchen		Lighting, Utilities, and Household Maintenance		Environmental Control, Recreation, and Personal Care	
Appliance	Average Annual Energy Consumption (in KWH)	Appliance	Average Annual Energy Consumption (in KWH)	Appliance	Average Annual Energy Consumption (in KWH)
Range	1175	Water heater, Standard	4219	Black and White Television	362
Refrigerator-freezer, 14 ft^3	1137	Washing Machine, Automatic	103	Color Television	502
Freezer, 15 ft^3	1195	Dryer	993	Air Conditioner, Window	1389
Dishwasher	363	Lighting[b]	---	Air Conditioner, Central[c]	---
Disposal	30			All-electric Heat[c]	---
				Heat Pump[c]	---
				Heater, rad.	176
Total	3900	Total	5315	Total	2429
Miscellaneous		Miscellaneous		Miscellaneous	
Broiler	100	Iron, Hand	144	Bed Covering	147
Coffee Maker	106	Iron, Mangle	158	Dehumidifier	377
Deep-fat Fryer	83	Water Pump	231	Fan, Attic	291
Frying Pan	186	Other	77	Fan, Furnace	394
Hot Plate	90			Fan, Roll-about	138
Roaster	205			Fan, Window	170
Other	144			Humidifier	163
				Radio	86
				Radio Phone	109
				Other	120
Total	914	Total	610	Total	1995

a) [Rand-73]
b) Consumption for lighting is determined by the coefficient 40.8 KWH/room-person.
c) Dependent on temperature variation in area of location of residence.

E-3 PATH REQUIREMENTS

E-3-1 INTRODUCTION

This appendix contains data on end uses of energy. Both futures (NEE and FTFB) make numerous assumptions about changes in the way energy is used in the future. The assumptions of the NEE are broader than those of the FTFB, containing all of the technology of conservation of the FTFB plus the assumptions of increased use of electricity. The electrical use is projected to grow from 16 percent (present) to 75 percent in the year 2000 in the NEE.

The FTFB future assumes nothing but medium term technology will be needed to achieve the conservation goals. This medium term technology includes only things which are proven as of today. The FTFB assumes that the barriers to commercialization of conservation technology will be removed in a very short time. The FTFB sets very large energy savings goals in the immediate future. In fact these goals are set so high, so soon, that no orderly growth process could achieve them. Some amount of mandated savings will be necessary to start the nation on the FTFB path. Figure E-10 displays the two points estimated by the FTFB for energy savings in 1985 and the year 2000. By the FTFB list of conserving technologies the nation is achieving very little along this path as of today (August 1974). At most we have the savings growing out of reduced speed limits and reduced driving which amount to about 2 percent or of the order of one hundred thousand bbls of gasoline per day (about .2 Quad per year). As the figure shows Ford projects 19 Quads of savings by 1985 and 65 Quads by 2000. In section 4 of this appendix we will discuss the impacts associated with starting the elements of the conservation scheme.

The NEE projects certain major long term technologies associated with both conservation and growth of electrical end uses. Because the inherent losses in conventional conversion systems from thermal energy to electrical energy represent almost two-thirds of the fuel energy, means must be found for increasing the effectiveness of electricity at the end use. Present end use technology is so inefficient in its use of fuels directly that electricity can greatly improve on the overall efficiency, fuel value-to-useful work. It should be recalled that neither the NEE nor the FTFB future contains assumptions about the long term technologies in conversion or distribution of energy. The technology assumptions of these two futures err on the conservative side.

E-3-2 CONSERVATION THROUGH TECHNOLOGY

In many places conservation through technology is called "painless" conservation. It is true that to achieve the goals of the FTF many new products and whole industries would develop. Thus strong positive effects would be seen in the creation of jobs and sales in primary, secondary, even tertiary industries. The principle requirement for success of this plan on the needed scale would be a healthy and stable consumer market and the absence of negative factors such as abundant fuels or energy at lower cost than conservation. Achieving large scale energy conservation requires a delicate balance between the market suppressing effects of higher energy cost and the motivation for conservation high costs

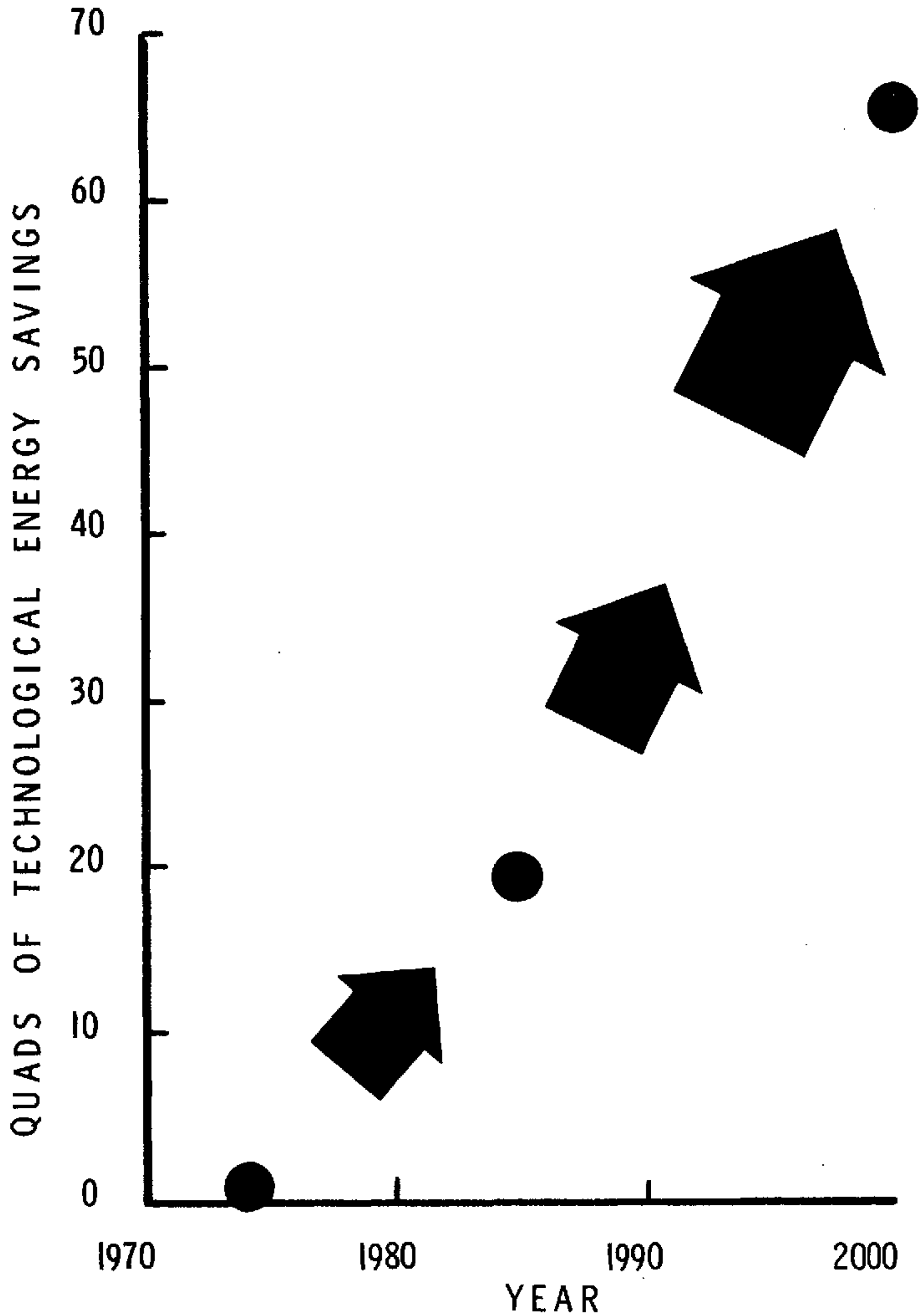


FIGURE E-10 STATEMENT OF THE TECHNOLOGICAL CONSERVATION GOALS IN THE FORD TECHNICAL FIX. THE GOAL 2000 A.D. OF 65 QUADS OF SAVINGS SHOULD BE COMPARED TO THE TOTAL 1974 CONSUMPTION OF ENERGY OF 75 QUADS.

generate. Further discussion of this is found in the sections and chapters on impacts.

To give the conservation requirements, the tables below list the opportunities and energy savings projected by the FTFB for the year 2000. Conservation through technology converts a 185 Quad economy into a 120 Quad economy.

Table E-44 shows the type of savings projected for the residential-commercial sector. These two sectors of the economy consume energy for similar purposes and use machinery which differs only in scale. Therefore the opportunities for savings and the technology for the two sectors will be essentially the same. The entry for solar heating and cooling is a reflection that this technology is close to demonstration and commercialization at 1974 prices. Use of solar energy in this sector has the best net energetics (1 year pay back of energy) [Terrastar-73] of any solar application. The use of heat pumps for increasing the effectiveness of electricity is well known and proven. Weakness exists in the reliability of the units and in the maintenance industry. Improvements in construction of homes and buildings are easily made on new work and can be justified on a retrofit basis in many cases [NBS-73]. Furnace and air conditioner efficiencies are subject to improvement. Furnace efficiencies are often overstated since maintenance is necessary for peak performance and considerable savings can be achieved through duct and flue insulation. Air conditioner efficiencies vary by as much as a factor of two for units of the same BTU rating. This efficiency is directly related to the cost and weight of the system and the sophistication of the controls. An indirect savings on air conditioning would come from eleminating pilot lights on gas appliances. It is estimated that 8 percent of all natural gas is consumed by pilot lights. The integrated utility system is another National Bureau of Standards program in conjunction with HUD and other federal agencies [Phillips-74]. By the estimates of realizable savings (30-35 percent of fuel input) the figure in the table corresponds to only 10 or 12 million people living under integrated utility systems. This is clearly a conservation opportunity with real expansion capacity. Water heating represents 4 percent of national energy consumption and is also a good ground for savings.

All conservation connected with commercial buildings and homes is tied up with construction rates and:

Zoning

Building Codes

Mortgage availability and insurance

Urban renewal

Government housing and other urban goals

Road and highway siting

Utility companies and control commissions.

In summary, 6.5 Quads of this saving is in improved direct use efficiency. The

TABLE E-44 FTFB PROJECTED SAVINGS (IN 2000), RESIDENTIAL-COMMERCIAL SECTOR [FORD-74]. UNITS OF QUADRILLION BTU.

Conservation Opportunity	Quads Saving Over Present Means
Heat pumps for space heating and possibly low temperature steam	5.4
Better construction of homes and buildings; insulation, insolation and infiltration	4.2
Furnace and air conditioner efficiency[a,b]	1.2
Integrated utility systems	0.9
Solar heating and cooling of buildings[c]	1.2
Others: lighting, water heating	3.6
	16.5[d]

a) Measurements of gas furnace efficiency are around 45 percent to 50 percent
b) Energy labelling would be a necessity.
c) Obviously not conservation per se. This use of solar energy is the one closest to demonstration and commercialization today and has the best net energetics.
d) Consumption without conservation is projected to be 53 quads.

other 10 Quads of savings is equivalent to regaining energy lost in the production of electricity. Some of this is direct use of rejected heat such as the integrated utility system while the rest is in increased effectiveness of electrical energy. The savings in heat pumps, integrated utilities, and lighting and water heating are savings in electrical use.

Table E-45 lists the type and amount of savings projected in the FTFB future in the transportation sector. Since this sector is greatly changed under the NEE future the reader should consult section E-3-3 with this one. The opportunities for savings in the transportation sector center on the automobile. It became very evident in the energy supply problem of 1973-74 that this end use was almost the only one with the capacity for rapid reduction. On the basis of efficiency this sector is one of the poorest. The overall energy input to useful work output of an automobile is estimated to be [Ross -73]

14.1 BTU crude oil $\rightarrow$ 1 BTU useful work.

The savings of 10.1 Quads for approximately 160 million autos represents 5-6 million barrels per day of gasoline. The savings associated with railroad use are very conservatively stated since on a ton-mile or passenger-mile basis railroads are more efficient than trucks or airplanes. Obvious problems already exist with the United States railroad system and curing these must come before large scale expansion of rail use can occur. Two Quads of the savings are associated with refining.

Table E-46 lists projected energy savings in the industrial sector [Ford-74 and Lazarides-74]. The largest savings is in the combination of on-site electrical generation with on-site steam use. Process steam is a major portion of industrial energy consumption but it does not utilize the full energy content of the fuel. Very attractive savings tradeoffs exist when fuel is burned to produce high quality steam, then electricity, then low quality process steam. Estimates of total costs of the electrical generating system and fuel costs show such systems can be profit making operations. Questions of off-site sale of surplus power are complicated by the need to synchronize supply and demand and the difficulty of matching power quality to utility grid standards.

Figure E-11 shows three versions of the percentage mix of the four sectors. The values of the four numbers are constrained because the total is fixed. It should be noted that the "historical" constancy of the sector percentages is an accident. The projections of [SRI-72] show an apparent constancy even though individual sector growth rates differ considerably at this time (commercial 5.4 percent, industrial 3.4 percnet). It is important also that the basic premises of the FTFB will alter the historical influence coefficients between gross national product and other financial indicators and energy consumption. The transition period, at least the next 25 years, will see many of the present influence coefficients change.

E-3-3 CONVERSION TO AN ELECTRIC ECONOMY

Table E-47 displays the important sector changes which will follow on major conversion to electrical use.

TABLE E-45 FTFB[a] PROJECTED SAVINGS (in 2000), TRANSPORTATION SECTOR [Ford-74]. UNITS OF QUADRILLION BTU.

Conservation Opportunity	Quads Saving Over Present Means
Smaller Cars (25 m.p.g.)	10.1
Aircraft efficiency and load factor	3.4
Convert short haul air and some trucking to rail	1.9
Truck efficiency	2.2
Other	1.9
	19.5[b]

a) Consult the section on transportation in the NEE future as well.
b) Consumption without savings projected to be 44 Quads.

TABLE E-46 FTFB PROJECTED SAVINGS (in 2000), INDUSTRIAL SECTOR [Ford-74]. UNITS OF QUADRILLION BTU

Conservation Opportunity	Quads Savings Over Present Methods
Heat pumps, combined steam and electricity production	13.3
Improved energy intensive processes	3.6
Metal recycling	5.4
	22.3[a]

Consumption without conservation is projected to be 78 Quads.

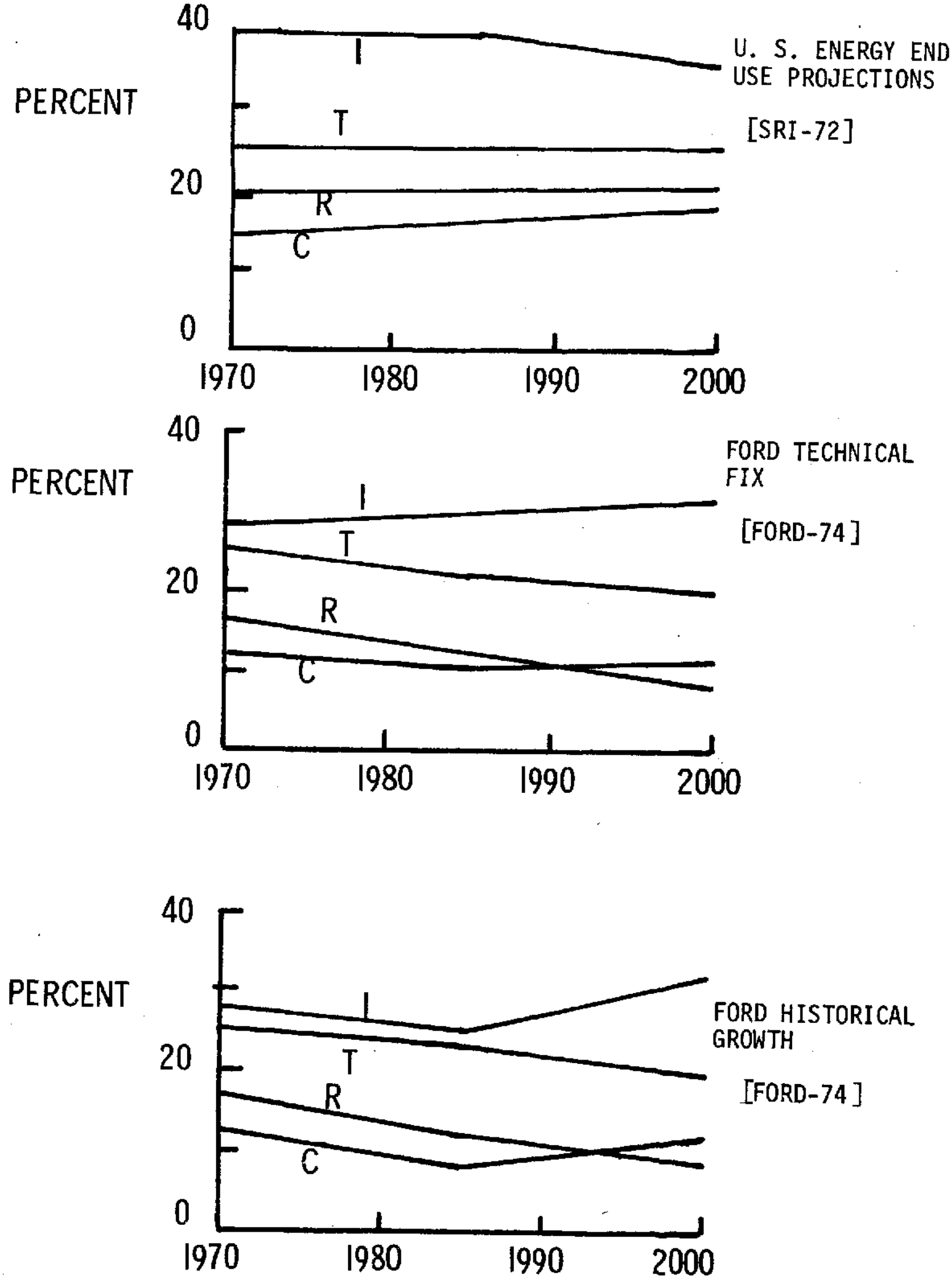


FIGURE E-11 END USE ENERGY CONSUMPTION BY SECTOR. CONSUMPTION IN PERCENT OF TOTAL FOR THE INDUSTRIAL(I), TRANSPORTATION(T), RESIDENTIAL(R), AND COMMERCIAL(C) SECTORS.

TABLE E-47 SECTOR INFORMATION
WESTINGHOUSE NUCLEAR ELECTRIC ECONOMY

Transportation Sector[a]

For 1985: 5×10^6 electric cars

For 2000: 100×10^6 electric cars
110 GW electric required for cars
130 GW electric required for trucks, trains & busses
[b]160×10^6 total cars
[b]25 mpg average fossil fuel mileage on automobiles

Residential Sector[a]

For 2000: 75 million homes heated electrically
30 million homes using electric heat pumps
Coefficient of performance for heat pumps 150-250 percent
60 GW electric for residential space heating
60 GW electric for other residential needs

Commercial Sector[a]

For 2000: 200 GW new electric to replace oil & gas

Industrial Sector[a]

For 2000: 360 GW new electric for extra process steam

a) [Ross-72]
b) [MVMA-74]

The projections of total numbers of motor vehicles follow closely on projection made without consideration of technological revolutions such as electric cars [MVMA-74]. The projections of total housing units and total commercial and industrial demands are also from projections independent of technology assumptions. The goal of the NEE is utilization of 75 percent of the gross energy as electricity. At present conversion efficiency of about 32 percent the available energy in the NEE would be about equally divided between net electrical output and direct fuel use. Electrical units stated in Table E-40 are in installed generating capacity. The NEE utilization factor is about 50 percent so 100 units of installed capacity (power) produce about 50 units (watt-years) of energy and consume about 150 units of fuel energy (32 percent conversion efficiency). The installed generating capacity includes all estimates for peak demands, programmed maintenance and refueling (nuclear) and system reserve.

The first requirement of the NEE is the extra 900-1000 GW of installed generating capacity allocated as shown among the sectors. The transportation sector is particularly bad from the point of view of peaking requirements. However, it is possible that transportation needs (mostly battery charging) can be supplied at night to offset day time peaks. The generating needs take this double utilization into account. These projections should be compared to present electrical end use data given in Table E-48.

The electric automobile is probably one of the most analyzed technologies in the energy, pollution debates. The figure of merit suggested in the NEE [Ross-74] is:

14.1 units crude oil	1 unit useful work in an internal combustion car.
5.3 units fuel	1 unit useful work in an electric car.

Thus the electric car is about 2 1/2 times more efficient on a direct utilization basis. The principle gain over the internal combustion engine is in the conversion of stored energy to kinetic energy. The stated benefit is 6 to 1 in favor of the electric car. This more than compensates for the 32 percent conversion efficiency in electrical generation. One of the principal requirements of the electric car is the battery materials. Candidates involve lead, nickel or zinc. This does not consider the many fuel cell or hiah temperature batteries under development. The U.S. lead and zinc supply is moderate to poor, [DOC-73]. The nickel position is very poor.* Any nickel use competes directly with stainless steels, nickel based superalloys, and many direct uses of nickel and cupronickel alloys. The manganese nodule discoveries may alleviate some of the pressure on world nickel and cobalt resources. Some estimates of commuter type electric cars (2 persons, 30 mile range) suggest little alteration in electrical generating and distributing capacity would be required [Sthulinger-74]. However, on the scale envisioned by the NEE which is essentially market saturation of the commuter and short range van vehicles, major generating additions would be required. One interesting aspect of the problem would be in the fact that consumption would be predominantly in the residential areas. This suggests much larger substations and distribution networks in the diffuse

*See Tables E-30 and E-31.

TABLE E-48 PRESENT ELECTRICAL END USE[a]
UNITS OF QUADRILLION BTU NET ELECTRICAL ENERGY[b]

End Use	Consumption
Transportation	0
Space Heating	0.2
Process Steam	0
Direct Heating	0.2
Electric Drive	2.0
Feedstocks	0
Water Heating	0.4
Air Conditioning	0.5
Refrigeration	0.5
Lighting	0.3
Cooking	0.1
Electrolysis	0.2
Miscellaneous	0.6
	5.0

a) [Ross-74]
b) Seventeen quads of energy are consumed to generate this five quads of electricity.

residential areas. This would reduce somewhat the focusing effect of the population centers on transmission line routes. It does however, increase the impact of rights of way, electromagnetic interference, audio noise, electrostatic hazards, and aesthetic damage on the highly valued suburban lands. The added generating capacity for transportion alone represents a 1 kW per capita addition to generating capacity. Present capacity is about 2 kW per capita.

Under the National Electric Code methods for calculating the service load, charging facilities for electric cars (night) would not add appreciably to service requirements. This is an extremely important benefit which would be preserved by incorporation of incentives for night use and disincentives for day use. An important part of the auto design would involve matching the charging voltage levels to the voltages available without massive filtering and/or large transformers or special service drops to the home. Some active elements (transitors or electronic switches) would probably be included in the power conditioning system. The influence of charging equipment on power quality and power factor would also require assessment. The motor in the car might be used as its own generator for charging.

The projections of residential heating methods indicates that resistance heating will still be a major factor. This is of interest to the general philosophy since electrical resistance heating does nothing to repay the conversion losses. Heat pump efficiency decreases in northern latitudes. Lifetime operating costs compare favorably with conventional systems throughout the U.S.

The commercial sector has more conservation opportunities due to scale factors than does the residential sector. Generally end uses and technology are similar, see section E-3-2. The industrial sector contains the potential for directly using power plant rejected heat in industrial park settings. Many studies and industrial activities are underway to spread conservation technology in industry [Brown-74, Phillips-74].

It is essential to the goal of NEE that oil and gas be replaced wherever possible. Table E-49, [Ross-74], displays some of the particular oil and gas savings. Transportation represents the major area of saving since it is the sector most specifically dependent on hydrocarbons. The only remaining oil use in 2000 is projected to be aircraft, trucks, and long distance automobiles. The only use of oil for power generation is in the use of the heaviest residuals which have little form value.

Particular requirements for an electric economy can be enumerated rather easily. Listing only those outside of power plant construction we have the general areas given in Table E-50.

TABLE E-49 PROJECTED OIL AND GAS SAVINGS IN THE NUCLEAR ELECTRIC ECONOMY [Ross-74]. UNITS OF QUADRILLION BTU.

Technology	Oil and Gas Savings (in 2000)	Electrical Increase
Electric Vehicle	8	2
Other Transportation	16	2
Space Heating	4	1
Other Residential	2	1
Commercial	9	3
Process Steam	10	6
Other Industrial	12	0
	61	15

TABLE E-50 GENERAL AREAS OF REQUIREMENTS FOR AN ELECTRICAL ECONOMY IN THE END USE CATEGORY

Motors
- Heat Pumps
- Cars
- Vans
- Trains

Heat exchangers

Controls
- Charging - and allocation
- Electric appliances
- Industrial equipment
- Integrated utilities
- Switchgear

Conductors
- Charging equipment
- Vehicles
- Space heating elements

Batteries

Safety equipment

Turbine generator sets for on-site steam-electric generation.

E-4 IMPACTS

E-4-1 INTRODUCTION

All impacts here and in the rest of the report are judgements by the design group, not the authors of the scenarios. The major end use changes in the two futures involve conservation methods and conversion to electricity. We list these separately. Chapters on the example scenarios will synthesize these with impacts from the other sectors of the energy system. We first discuss the conservation related impacts since these are common to the example scenarios, then we cover the impacts related to increased electrical consumption. The end use technologies specifically mentioned in the FTFB are:

Residential/Commercial
- Heat Pumps
- Furnace and Air Conditioners
- Insulation and Construction
- Solar Heating and Cooling
- Integrated Utilities
- Water Heating
- Lighting

Transportation
- Smaller Cars
- Aircraft Efficiency and Load Factor
- Increased Rail Use for Freight and Passenger

Industrial
- Process Steam Combined with Electricity Production
- Energy Intensive Processes
- Metal Recyclying

For each of these topics we will list some impacts and rank them by displaying a symbol indicating the direction of the impact and relative importance as follows:

+ Indicates the impacted area or benefit or action or consumption increases.

0 Weak Effect

- Indicates the impacted area or benefit or action or consumption decreases.

Signs such as [++] or [--] indicate major impact areas. The reader should not interpret the plus and minus sign notation as indicating desirable or undesirable aspects of the impact.

In listing impacts we follow the categories of Chapter 3. We do not believe this list to be exhaustive. One reason for a limited impact list is to allow time for application of the methodology of alternate path analysis to at least two paths. A detailed impact analysis of just one path is more work than the group could have accomplished.

E-4-2 CLASSIFICATION OF IMPACTS FOR THE EXAMPLE CASES

The impact discussion is organized by the general conservation opportunities listed above. These opportunities fall into classes

FTF and NEE:

- Conservation by reduced demand, e.g., insulation.
- Conservation by maximum utilization of the energy form value, e.g., heat pumps.
- Conservation by tradeoff, e.g., decrease electrical generation efficiency to sell waste heat at a higher temperature.
- Conservation by tapping renewable resources, e.g., solar energy.

NEE: Electrification

General Impacts

The goal of conservation by technology, especially of such enormous magnitude as found in the Technical Fix, has great impacts in the following areas.

Insufficient use is made of existing methods for disseminating new technology. Problems also exist in carrying new technology far enough that the private sector will make decisions simultaneously at the production and marketing ends to hasten the introduction of new technology. In a rational planning atmosphere such as we deduce as a requirement for an energy goal future technology transfer becomes mainly a function that is carried out by governmental agencies. Introduction of new technology has always been difficult for any entrepreneur. It is aided by the existence in some industries of fast response standards committees from the profession. The major engineering societies are leaders in this aspect of technology transfer. NASA, the National Aeronautics and Space Administration, has been a leader in organizing, documenting, and disseminating the varied technologies and evaluations which its mission has produced. If true long range planning of national energy policy comes into existence, an activity such as NASA's programs in technology utilization will be essential.

In the area of economic impacts, in general the conservation goals will generate many secondary and tertiary industries and businesses. In this sense the high cost of energy which is almost the sine qua non of voluntary capital investment for conservation will be partly offset in an overall economic picture.

In the area of social and political impacts, achieving the major conservation goals could well require social and regulatory incentives. The need for non-economic incentives could well arise if fuel supplies and interfuel competition produce price stability during the 75-2000 transition period. Further impacts in this area follow from the definition of a national energy goal. In particular, there would be increased participation of technically trained individuals in policy making. This might take the form of increased participation in government staff positions [Andelin-74], increases in technically trained elected officials, increased organization of technically trained individuals into interest groups [Miller-74, Tucker-74]. Education of engineers and scientists will increasingly cover conservation methodology. Education for non-technical goals would increase emphasis on not only science and scientific method, but also the engineering methods such as systems analysis and technology assessments. Some general problems in definition of new professions exist. In particular, the environmental area is still not clearly delineated. Problems of the environment are multidisciplinary so that expertise in this broad profession should be based on training in:

Health and Medicine

Bio-sciences

Engineering

Physical and Social Sciences

Economics and Law

The value of this list is simply to emphasize the super human qualities of the non-existent indiviudal "the environmentalist." A real need exists for program definition in fields as complex as environmental impact assessment. Initial moves are being made to consolidate expertise in this complex field and in training practioners [Albers-74]. Parallel remarks apply to designations such as ecologists and technology assessors. An article directly addressing this subject is given in [Natusch-74].

The existence and improvement of a state-of-the-art transportation network is another overriding impact of these scenarios. By definition, we should replace inefficient modes of transport by better ones. Since by 2000 the economy is projected to grow to something on the order of 3 to 4 times its present size [EPA-73], the transport system would grow apace. One estimate by the Rand Corporation [Rand-73-2] shows that historical growth of airlines would lead to a consumption of 100 Quads of energy by aircraft alone in 2000 A.D. Energy use of this magnitude by such a specialized sub-sector of the economy is larger by at least 10 times than that provided for by the author of the example scenarios.

In the area of government policy, many impacts appear. The simplest consideration is that the magnitude of activities in the energy system and the relative few participant corporations will require close supervision,

if not outright regulation or even nationalization. Growth and change in many aspects of our economy are inherent in achieving any of the scenarios examined (cf Chapter 5). Actual growth of energy consumption is not a requirement of economic growth in all scenarios (see Ford ZEG case in Ford-74). However, major change within the patterns of energy resources and consumption is a universal scenario feature. Thus, events involving

Large expenditures
Large fractions of the labor force directly
Basic commodities in large quantities
Large profits
Large segments of the population
Large segments of the federal laws
Large segments of the federal burearcracy

are afoot in all scenarios.

E-4-3 IMPACTS OF CONSERVATION GOALS

Table E-51 lists some impacts related to the transportation sector, In this sector, the conservation technology is much more limited in the FTFB and AFTF examples than it is in the NEE

Table E-52 lists some impacts of technology related to conservation through reduced demand.

We do not list in this appendix the impacts of conservation by tapping renewable resources. In the FTF and NEE scenarios this is translated into a small use of solar energy in simple heating and cooling applications prior to the year 2000. The whole subject of solar power is confused by struggles between advocates of nuclear and non-nuclear sources for our ultimate (non-fossil)future. We do not include impact analysis of solar energy for two reasons:

Appendix C reviews it adequately.

Solar energy is an exogenous factor to these scenarios prior to 2000 A.D.

The last statement is to be interpreted to mean that major breakthroughs in solar central power technology would act as a very strong depressing factor on nuclear (fission and fusion) development. Significant success in solar energy or any renewable resource would also depress interest in conservation in any other form.

Table E-53 lists some impacts related to conservation by maximizing utilization of available energy.

TABLE E-51 IMPACTS OF CONSERVATION BY REDUCED CONSUMPTION IN THE TRANSPORTATION SECTOR

Note: the NEE adds to this conservation by maximizing utilization.

Automobiles

Brief Characterization	Rank
Design of More Efficient Motor Vehicles (Internal Combustion)	++
Fabrication Technology	+
Size of Auto Industry	0
Special Purpose Vehicles--Private Use	-
Consumption of Aluminum	++
Consumption of Non-metallics: Glass, Plastics	++
Consumption of Rubber	-
Pollutants	--
CO_2	0
CO	--
SO_x	0
HC	--
NO_x	-
Particulates	-
Lead	--
Water Vapor	-
Noise	-
Land Use - Roads	0
Filling Stations, Refineries	--
Waste - Scrap Bodies	-
Economic	
Demand for Capital	0
Wages	+
Prices of Autos	+
Price of Energy	0
Gross National Product	+
Social/Political	
City Design	
Housing	+
Public Transportation Intracity	-
Personal Auto Dependent Businesses	0
Road Building - Super Highways	-
Regular Highways	+
Public Transportation Intercity	+

TABLE E-51 (Continued)

Government	
Inspection	++
Performance Standards	+
Speed Limits	-
Health and Safety	++
Insurance	0
Inspection and Enforcement	+
Aircraft	
Technical	
Design of Low Speed Aircraft	+
Design of Jet Aircraft	-
Design of Cargo Aircraft	-
Scheduling of Flights	-
Optimization of Schedules	+
Flexibility of Schedules	+
Environment	
Pollutants	
SO_x	0
Particulates	-
NO_x	--
CO	--
Hydrocarbons	-
Land Use	
Airports	-
Noise	-
Economic	
Capital-Fleet Replacement	-
Wages	0
Price of Energy	0
Gross National Product	+
Exports--Aircraft	+
Social/Political	
City Design Requirements	+
Public Transportation--Non-Air	+
Air	+
Education	
Pilots, Flight Crews	+
Support Personnel	+
Government	
Efficiency Incentives	+
Subsidy of Design	+
Subsidy of Airports	-

TABLE E-52 IMPACTS OF CONSERVATION BY REDUCED DEMAND

Brief Characterization	Rank
Performance Standards for New Construction, Appliances	++
Design of Retrofit Systems for Old Construction	+
Design of New Construction	+
Safety	
Fire Standards	++
Chemical Hazards	+
Operating Hazards	+
Environmental Impacts	
Pollutants	-
Economic	
Capital--Individual	+
Industrial	0
Price of Energy	+
Gross National Product	+
Social/Political	
House Siting Design	+
Multi-family Dwellings	+
Single-family Dwellings	-
Education	0
Skilled Labor	0
Professional Employment	0

TABLE E-53 IMPACTS OF CONSERVATION BY MAXIMIZING UTILIZATION OF AVAILABLE ENERGY, RESIDENTIAL, COMMERCIAL AND INDUSTRIAL SECTORS

Brief Characterization	Rank
Low Grade Heat Becomes a Commodity $20 Billion (1974 prices)	+++
Design of all Types of Structures	++
Heat Exchanger Systems	++
Heat Exchanger Critical Materials	++
Control Systems, Supervisory and Decision Making	++
Fabrication Techniques	+
Installation and Maintenance Industries	++
Pollutants	-
Capital Costs	++
Payrolls, Jobs	+
Price of Energy	0
Education, Technical	+
Professional	0
Siting of Power Plants and Industries	++
Siting of Power Plants and Non-industrial Activity	0

E-4-4 IMPACTS OF ELECTRIFICATION GOALS (NEE)

The electrification argument goes:

Resources are remote or diffuse and are finite.

Conversion methods achieve efficiency through scale.

Conversion methods favor generation of electricity.

Distribution of electricity is safe and efficient.

Fuels other than fossil are difficult to use in other than electrical generation.

Therefore, electrical use must increase.

The electrification goal entails an obligation to increase efficiency because:

Electrical generation methods are severely limited in efficiency [35%, speculative attainment of about 50%].

Efficiency improvements are relatively easy to achieve because:

Direct use of fuels are presently very inefficient (automobiles are ~7% efficient).

Efficiency in the use of electricity can be achieved in two ways:

Direct - Utilization of rejected heat directly at the power plant.

Indirect - Replacement of inefficient direct fuel use by efficient electrical use.

The indirect method includes the heat pump technology discussed previously and the particular replacement in the transportation sector. The direct efficiency improvement has also been discussed.

<u>Transportation--Electric</u>

Because the transportation sector is a very large segment of United States energy consumption (~25%) the potential for consumption of energy in any form is large. This is contingent on technology for using energy in a given form and on incentives such as economy or conservation. The internal combustion engine has such a poor overall performance that it can be improved upon readily by electrification. The efficiency gain is of the order of 2 1/2 times over gasoline engines even when conversion losses in the generation of electricity are included.

The technology options and transportation systems options for electric cars are some of the most thoroughly assessed areas in all of engineering. This emphasis is justified by the large potential payback in direct and indirect benefits. Many of the studies concentrate on the problem of overcoming marginal feasibility in today's market. The interest is conservatively medium range in the NEE scenario. The electric car becomes significant in 1985 and dominates by 2000 A.D. The supposition is that technology needs 10 years to achieve commercial performance levels. From that point on an orderly replacement market of electricity for gasoline cars can probably achieve the NEE goal of 100,000,000 units by 2000 A.D. Production is of the order of 6 to 7 million per year. This goal is two-thirds of the auto market, probably saturation levels because the distribution of driving patterns contains about this much short trip driving.

It is probably not worth detailing the impacts of the electric car further because the exact vehicle parameters are uncertain and subject to large changes. The technology of batteries is being intensely explored. Some discussion of the electric car is given in section E-2.

Other electric transportation is described in the NEE. This includes intracity transport and 100 percent conversion to electrified railroads. The intracity transportation is a scaled up version of the electrified car. The electric railroads on the other hand pose some unique impacts worth listing. Table E-54 lists some impacts associated with an expanded all electric railway system.

E-4-5 EXOGENOUS IMPACTS IN END USE

These external influences can be described readily for the example cases because the authors are explicit about the implementation scheme. Each detail of the implementation scheme defines a set of exogenous impacts which can effect the outcome of the scenario. Exogenous impacts are loosely limited to upsetting factors for the purposes of this discussion.

Failure of any major component of the conservation program would have great impact on these scenarios. The fuel mix shares and growth rates of the components of the mix are coupled fuel-to-fuel. Factors such as interfuel competition and lack of economical ways to achieve production capacity in excess of demand suggest most scenarios will lack a quick-response capability.

The failure of the conservation objective would throw increased pressure on all the other components of the mix.

E-4-6 SUMMARY

Impact statements and rankings have been displayed for the technologies characteristic of our example scenarios. These have been described at the future point. Impacts associated with the path to the future point are detailed in the chapter dedicated to each example path. In particular, the methodological goal of assessing a future with the aid of assessments of

TABLE E-54 IMPACTS ASSOCIATED WITH AN EXPANDED ALL-ELECTRIC RAILWAY SYSTEM

Technical	
Systems Design of Modern Rail Transport.	
Every design paramater should be reassessed.	+++
Fabrication. Total Systems Redesign.	+++
Environment	
Pollutants	-
Land Use	+
Noise	+
Materials	
Roadbed and Trackage	++
Rolling Stock	++
Controls Systems	++
Conductors	++
Superconductors	+
Economic	
Capital Demand	+++
Wages	+
Price of Energy	0
Gross National Product	+
Local Tax Base	++
Social/Political	
City Planning	++
Roads	-
Public Transportation	++
Education--Technical	++
Education--Professional	+

alternate paths will generate a new type of impact analysis in which two similar paths help in establishing the importance of otherwise vaguely ranked impacts.

A lack of quantitative impact analysis is not a deficiency of this method since in proposing the method and the example scenarios it is hoped that the variation of path process emphasizes the most important impacts. This method has tenuous connections to many recognized statistical treatments of data where a tradeoff is made between the number of test cases and the precision of the data in any one case.

Impacts denoted by multiple plus signs receive some specific comment in Chapters 8 - 10.

APPENDIX F. SUMMARY OF SPEAKER'S SEMINARS

The many speakers who conducted seminars for the 1974 NASA/ASEE Faculty Fellowship Program in System Engineering Design at the Marshall Space Flight Center and which was directed by Auburn University provided invaluable resource material for the 18 professors who participated in the program. The summaries given in this appendix are the paraphrased remarks of each speaker and in some instances the opinion or impressions of the faculty fellows are interwoven into the fabric of the summary. The summaries are arranged in chronological order.

A HYDROGEN ECONOMY

Derek P. Gregory
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The Institute of Gas Technology has an ongoing program to study hydrogen as a future fuel.

Some advantages of hydrogen are that it is cost competitive with electricity, easy to move through pipelines, and easy to store.

Dr. Gregory stated that there is a need for a fuel with large reserves and low pollution and with no need to recycle the material, e.g., burning Al or Zn. Carbon containing compounds combust to CO_2 which may lead to a global greenhouse effect. Some fuels which fit these criteria are hydrogen, ammonia, hydrazine, metranol. However, ammonia and hydrazine both require hydrogen in their manufacture.

There are three methods of obtaining hydrogen by dissociation of water: electrolytic, thermal and thermo-chemical.

A 36" gas pipeline at 700 psi has an energy transmission capacity equivalent to 11000MWe. The lifetime of a pipeline is 30-40 years. At ground temperatures, 700 psi and normal pipe steel, there shouldn't be a problem with hydrogen embrittlement.

Flow properties are proportional to square root of the density. Hydrogen flow is 3 times faster than methane, but the energy content of hydrogen is 325 BTU/ft^3 vs. 1000 BTU/ft^3 for methane. So to a first approximation the same pipeline carrying hydrogen or methane will carry the same amount of energy per unit time, but a bigger compressor and a bigger engine are needed for hydrogen so there is a greater transmission loss for hydrogen than for methane. Now compare a charge of $17¢/10^6$ BTU for methane vs. $\$4/10^6$ BTU for hydrogen. One can move H_2 through the pipeline at 750 psi, but the optimal pressure is 2000 psi, which would cost 2-3 times the amount for moving natural gas. Electrical transmission in a 765 kV line is a minimum of $9¢/10^6$ BTU for 100 miles. The average is $20¢/10^6$ BTU with underground transmission costing 40 times more. Gas transmission including pumping and leaking has a 15% overall loss.

Relative Price on Energy Forms 1970 in $\$ /10^6$ BTU

	Natural Gas	Elec.	Electrolytic H_2
Production	.17	2.67	3.23
Transportation	.20	.61	.45
Distribution	.27	1.61	.34
Total	.64	4.89	4.02

The $\$2.67/10^6$ BTU for electrical distribution corresponds to 9 mils/kWh. The electrolytic H_2 column assumes all power plants are making H_2 and also assumes that the distribution cost of H_2 is 50% more than for gas. The numbers are averages and estimates. Conclusion: Hydrogen is competitive with electricity.

Natural gas is presently stored as a liquid in urban areas for seasonal use. Storage is an important consideration since nuclear (thermal plant) output is constant, solar is daily and demand has a seasonal and daily variation. Gas can be stored in underground rock formations. This is done now for winter storage. 1/3 of the storage is "cushion" gas and can't be recovered at present. Total gas storage capacity in the U.S. equals total electric output. The energy of a gallon of liquid hydrogen is 1/3 that of a gallon of gasoline. Liquid hydrogen trucks have to be vacuum insulated and are more expensive than LNG trucks.

Small power plants to convert H_2 back to electricity should eliminate SO_x and particulates, but would still produce NO_x.

Mr. Gregory mentioned the 12 kW fuel cells built by Pratt-Whitney. They run on natural gas which is converted to H_2 and then used in the fuel cell. This process is not subject to the carnot cycle. The process is 40% efficient from natural gas to electricity.

The Hydrogen Car

Present efforts to build a hydrogen powered car have been mostly student projects--just put on a propane carburetor and changed the timing a little. Can take off all emission control devices. Hydrogen has an octane rating of 110. Lead isn't needed and designers can go back to high compression ratios. NO_x is lower with hydrogen than natural gas, perhaps because hydrogen burns without hot spots. There is some CO/CO_2 from burning oil, but a hydrogen car will easily pass the '76 emission standards. The problem is how to store sufficient fuel. A standard lab tank weighing 124 lbs empty will hold 1 lb of hydrogen, which is sufficient to drive the car full throttle for 6 minutes.

Airplane - L-1011 Hydrogen Version

Such a plane would have 10.4 ft. diameter wing tip fuel tanks. Hydrogen weighs 1/3 that of jet fuel, but the tanks weigh 1/3 more so there is a net saving in weight of 1/3. There is a safety bonus because the tanks are at the end of the wing. Fully loaded, the take-off weight would be 2/3 that of a standard jet, so design could employ smaller engines, more payload, faster climb. The disadvantage would be the necessity of a hydrogen facility at every airport. In 1956-60, the USAF had a B-57 bomber that had one engine fueled on hydrogen. In '50s Lockheed designed a plane to fly around the world on hydrogen, but built the U-2 instead.

The Hindenberg

The safety problems are similar to those of natural gas and propane. However, the ignition energy of hydrogen is 1/10 that of methane or propane and could be ignited by a spark from clothing, hair, etc. Hydrogen also has a wider flamability ratio with air than methane. (4 to 75% vs. 5 to 15% respectively). Hydrogen could be odorized like natural gas and thus would be detectible by odor well below the 4% concentration. Hydrogen leaks 3 times faster than gas, but with only 1/3 the BTUs the explosion would have the same energy content. The hydrogen flame doesn't radiate as much as gas and it also rises faster so that a hydrogen fire is less damaging. Hydrogen has a negative Joule-Thompson coefficient and warms upon expansion. It will auto-ignite at pressures greater than 2000 psi. Natural gas is now supplied at 6" of H_2O pressure to the home and is 1/2 that in appliances.

Conclusion

In order to produce the hydrogen necessary to meet the natural gas deficit in 2000 would need an additional 700 1000MW nuclear plants (in

addition to 1000 nuclear plants planned for electric power generation). So we will have to decide quickly in order to be able to build all the nuclear plants on time.

AGA has a long range research plan for hydrogen, but doesn't think it will be in use before 1995.

Reference

D. P. Gregory, "A Hydrogen-Energy System", American Gas Association, Chicago, 1973, Catalog No. L-21173, $20.

THE OUTLOOK FOR NATURAL GAS

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The gas industry provides 32% of our nation's energy. If transportation is not considered 50% of the nation's energy input is gas. In 1973 22.5 trillion ft^3 gas was used, 16 trillion by the public utility sector and the remainder by large commercial users.

Organizations similar to EPRI will be formed to sponsor high priority research. The AGA is a trade organization of regulated gas companies. Joint research projects are allowed by the FTC. The IGT is a separate research organ for the gas industry.

Proven reserves last year were 250 trillion ft^3. Of the 250 trillion, 31 trillion is in Alaska.

The probable gas reserves are 1150 trillion ft^3 (Includes Alaska and continental shelf to an ocean depth of 1,000 feet.) There is a probable 300 trillion ft^3 of tight gas in the Rockies for a total estimate of 1450 trillion ft^3.

The deeper one drills, the more one is likely to find gas rather than oil (greater than 30,000 feet) but the drilling technology is not present and the surveying technology is also weak.

We want to import as much as we can. The risk of depending on uncertain imports is worth the consequences.

Social costs should be built into price of products. Environmental standards can be rolled into prices also. Unconscionable profits should be industry limited.

Ethical - every residential customer should be treated alike - or should he? In a fixed product supply market which begins to fall, which customer is to be incrementally cut off?

ENERGY OVERVIEW

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Shell Oil is an energy corporation in that it has interests in oil shale, tar sands, lignite, bituminous coal and nuclear power. Shell is a multinational corporation in the broadest sense. Its stock ownership is 30% American and 70% Dutch Shell.

A primary consideration in forecasting future energy needs is population. The basis for Shell's study is the Series E Projection, 1% AAI (Average Annual Increase). Starting with a 1970 population of 205 million, the prediction is that the 1990 U.S. population will be 251 million.

The National Energy Policy will:
- Favor development of domestic resources
- Balance environmental and energy needs
- Develop national land use policy
- Allow deregulation on the price of new gas
- Conserve energy and encourage efficiency
- Maintain imports at lowest possible level.

It is anticipated that there will be continued economic growth with a 3% AAI inflation with the GNP declining from 5.7% in the '71-'75 period to 3.8% in the '80-'90 period.

Developments that will have a significant impact on the energy picture are geothermal energy (available now), breeder reactors (1985-2000), tele-communications to replace transportation (after 1990), nuclear fusion (2000), solar energy for residential use (1985) and solar energy for entral power electrical generation for use by the utilities (after 1990).

Our recoverable fuel reserve estimates and the percentage of the total energy reserves are:

Coal	150 billion tons	71%
Shale oil	80 billion bbl	10%
Gas	290 trillion cubic ft.	7%
Crude Oil	47 billion bbl	6%
Uranium (LWR)	580,000 tons	6%
Uranium (FBR)	70 x 580,000 tons	--

Our present consumption (1973) of coal is 600 million short tons annually but this is expected to rise to 1400 million tons within a decade or so. Some of our coal is under contract to foreign users, such as the ownership of West Virginia coal by Japanese interests. On the other hand, New England utilities are buying Polish coal. We export about 10% of our coal (mostly metallurgical). A massive increase in coal usage is hampered by limited transportation facilities and insufficient numbers of mine workers, among other things.

According to World Oil Magazine, there are 34,000 wildcatters who drill for oil with a 16% success rate. The vital factor is that natural gas is usually found in conjunction with oil, so that oil exploration directly bears on the finding of new gas wells.

If we draw upon the Alaskan oil reserves at a rate of 2 million bbl/day, assuming that present reserve estimates are correct, it will last 16 years.

The U.S. was self sufficient in fuels until 1971. At present, we are producing 9.4 million barrels of oil per day. Russia is self sufficient in fuels and China could be if it had adequate mechanization. At the present time we are competing with Japan and Western European for Arabian oil.

The price of Arabian crude oil at various times is listed below:

Jan. 1, 1971	$ .99/bbl
Jan. 20, 1972	1.44
Jan. 1, 1973	1.51
Oct. 1, 1973	1.77
Oct. 16, 1973	3.04
Jan. 1, 1974	$7.00

Unquestionably, we must develop an energy conservation ethic. It must be an international effort involving especially the West European nations and Japan.

In order to secure a greater share of the profit, the Arabians are building their own refineries and plan to market the finished product.

New construction in the energy industry represents 1/12 of the total construction in the U.S. Anticipated construction is in refineries, utilities, petrochemical plants, substitute natural gas production, deepwater ports and pipelines.

The anticipated needs for energy industry construction from 1973 to 1980 are $20 billion annually, 32,000 engineers, 70,000 welders and pipeline workers and 400,000 field construction men. In order to supply these demands, we must have 12,000 engineers, 25,000 pipefitters and welders and 100,000 field construction men in addition to those presently available.

SOLAR POWER

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Dr. Spencer, who was formerly with NSF (with an interest in solar energy), addressed the following topics:

Solar Energy and Solar Thermal Conversion

43,000 sq. miles could produce sufficient electricity for the complete U.S., but can we convert it at a reasonable cost?

Limiting characteristics are a peak flux of $1kW/M^2$, a day-night cycle and variable weather.

Solar Heating and Cooling of Buildings has first priority over other uses of solar energy.

NSF has solar energy programs in:

- Heating and cooling of buildings
- Photovoltaic conversion
- Wind energy conversion
- Ocean thermal gradient conversion
- Bioconversion

Conclusions

Solar-to-electrical most competitive for intermediate or peaking applications.

Solar total energy systemsare alternative applications.

Central receiver systems are most attractive for electrial power production.

Non-concentrating of low concentration systems are most attractive for total energy applications.

No fundamental technical breakthrough required; however, a major focus on engineering programs is required.

ENERGY INTENSIVE INDUSTRIES

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Industrial Energy Analysis Project
Bureau of Domestic Commerce
U.S. Department of Commerce
Washington, D. C. 20230

Mr. Glancy's work at DOC has centered around "Project Independence" and has divided logically into three phases:

Allocation of raw materials and energy sources,

Conservation of same,

Restructuring existing industrial facilities,

with emphasis on phase (3).

The object of the study is to fill in a requirements and constraints matrix, beginning with some given set of requirements and determining the corresponding constraints and their interdependencies; e.g., the main constraint facing the coal industry is the lack of new drag lines which are presently back-ordered to 1979 because of a steel shortage, etc.

A similar study is being conducted by DOC in which a given set of constraints are assumed, and the corresponding impact on energy supplying industries investigated. The study is not yet documented.

In regard to "Project Independence" a stable dependency would be a more realistic goal than total independence. For example, limestone (for cement) and iron ore (including scrap) are our only self-sufficient materials over the next 40 years.

A highly-tuned, optimal energy system does not adapt to changes. Such a system must depend on an energy/dollar equivalence which doesn't exist in our dynamic economic system. A sub-optimal but flexible national energy system utilizing swing fuels is the answer. The lack of correlation between energy cost and price is aggravated by governmental controls. The best solution is not to apply hard control but to provide incentives, and retain strong private enterprise.

Highly energy intensive industries include food (packaging and processing), lumber and paper, plastics, chemical, petroleum, cement, steel and other metals, transportation and glass.

The most critical raw material shortages are aluminum and titanium.

In the near future per capita energy consumption will go up world wide but will go down in the U.S.

FUEL SUPPLY VS. PRICE

Milton F. Searl
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Electric Power Research Institute
P. O. Box 10412
Palo Alto, California 94034

Preliminary definition of concepts and terms:

Cost-Price - Assumed interchangeable terms under conditions of economic equilibrium.

Economic equilibrium - Rarely achieved - a period during which the "law" of supply and demand operates and relationships of suppliers are strongly competetive.

Consumption-Production - Specific quantities - directly measurable.

Demand-Supply - Not directly measurable quantities since they depend on estimates of price and the consumer judgment on price levels.

Need - There is no quantitive meaning to the term need, it is not to be considered a driving force of the economy.

Domestic oil production capacity has not really peaked because of shutting in Santa Barbara, delaying Alaska Pipeline, and maintaining Naval petroleum reservations and failure to open up Atlantic offshore.

Recent profit levels have increased to the point that domestic supplies will increase provided material-manpower bottlenecks do not stop expansion. Expansion is not currently resource limited. See the NAE study on physical limitations to expanding the oil supply.

Mr. Searl anticipates that much better uranium ore bodies remain to be found since exploration technology has been very limited to date. The AEC estimates only 10% of likely areas have been explored, mostly in west. Commercial production may be possible to depths of 4000 feet.

Mr. Searl opinioned that there is no choice except to expand domestic oil, gas and coal. Coal transformation has great problems. We must expand the fuels with the largest bases to satisfy requirements out to 1985. This will give more freedom between now and then to plan for 2000. We will not need technologies like coal gasification before 1990 if we expand domestic fossil fuel production. Shale oil is the most economic alternative but not the best environmental one.

Natural gas price vs production estimates that 90¢/MBTU looks like the upper price limit for 1985 but this is still a bargain price especially environmentally. Historically gas has sold at 1/3 the price of oil on a BTU basis perhaps because gas wells produce three times the number of BTU's as oil wells (on the average).

Gas will become available for consumption as more storage facilities are built and as large use interruptible service customers like power stations are prohibited from using gas anymore.

We will not be resource limited by 1985 but will be approaching such a limit rapidly at that time.

MODULAR INTEGRATED UTILITY SYSTEMS (MIUS)

Clinton W. Phillips
Chief, Mechanical Engineer
Building Environment Division
National Bureau of Standards
Room B114, Bldg. 226
Washington, D. C. 20234

Mr. Phillips addressed the general areas of energy utilization and conservation as well as the topic of modular integrated utility systems.

Energy Utilization

Cheap energy philosophy has brainwashed designers and owners of environmental control systems for buildings. As an example, heat pump technology is 25 years old but higher first cost still limits application. It is cheaper to install a furnace for heating and add on air conditioning.

Attempts to cut down energy utilization are difficult with present systems. As an example, the cheapest equipment cost for air conditioning in large buildings is obtained by the reheat system in which all air is cooled to 60-65°F and then heated to specific room requirements. To cut down energy consumption, the reheat is eliminated, which results in cold rooms.

Present practice in dealing with more expensive fuels is to pass the incremental cost on to the consumer through a fuels adjustment clause.

Simply raising energy cost is not an acceptable solution. Also, government spending sprees are helpful at the research and development level but time is required before payoff.

Energy Conservation

The first step toward implementing conservation is to identify practical targets. Industry is a good target because energy is a direct cost in industrial operations but transportation is a limited target because there are no alternative solutions at a reasonable cost.

Rationing is unpopular because someone must start it. The easier political path is to allow prices to rise until, for example, a traveller is discouraged from taking long trips.

A conservation ethic will precipitate renewed interest in old technologies. Two examples are: small turbines with compressors can drive heat pumps and Stirling engines which have heat recovery potential and can operate on a variety of fuels. A small Stirling engine can run at 40 percent efficiency.

In the building industry, present codes are at odds with conservation. Standards for energy use are still in an infancy stage and must go through the throes of adoption. One example is the attempt to write a uniform code for energy conservation in new buildings which met resistance by the electric utility industry because the code claimed that resistance heating wasted fuel. Also, the air conditioning/heating industry did not want individual members hurt. Another example shows that even though simple

ways exist to cut heat loss by existing technology (namely, eliminate glass areas, seek proper solar exposure, eliminate reheat and install insulation) conflicting numbers and opinions can be generated.

In writing new standards, a quantitative statement of what is wanted (performance criteria) seems better than a specific method to construct a given component (building or material code). The shift to performance criteria is difficult; however, in establishing the performance criteria for Operation Breakthrough, a component as fundamental as a floor had to be reexamined in order to establish real numbers to reflect desired strength, stability, and fire resistance.

Modular Integrated Utilites System

To serve buildings efficiently power must be generated and conserved. A practical way to conserve energy in buildings is to look for ways to utilize the waste heat.

MIUS is sponsored by HUD whose charter specifies HUD in the role of advisor as to how utilities may better serve community residents including serving their social, economic, and aesthetic requirements or desires.

MIUS Program Steps:

Determine if better efficiency of overall utilities services is possible.

Integrated subsystems which provide each service to get the overall system effectiveness.

Recognizing the need to tie MIUS to outside utilities, seek ways to improve external utilities to better handle a MIUS served community.

By providing all electric, heating, air conditioning, water and solid and liquid waste treatment and disposal services, MIUS seeks:

Conservation of resources.

Decrease of 35 percent in overall energy use compared to separate utilities.

Minimum environmental impact.

Scheduling compatible with development or redevelopment plans of communities.

Elimination of the impact of new housing on existing waste treatment facilities.

Guaranteed emergency operation utilities.

Lowered cost.

Progress to date includes:

Unofficial feeler put out for developers interested in being participants. Favorable response was overwhelming.

Official RFP to be let this summer calling for demonstration of the concept by late 1976 in a selected plant within 50 miles of a good airport. The demonstration plant is to be fabricated from available articles of commerce.

Demonstration of alternate power, heating, air-conditioning and thermal storage devices is planned for a laboratory already built in the New Jersey area.

Small scale modular integrated systems test (MIST) on line and operating at Houston.

National Academy of Engineering Advisory Panel assisting as devil's advocate.

ECONOMICS OF ENERGY

Hendrick S. Houthakker
Professor of Economics
Harvard University
Cambridge, Massachusetts

Economists do not believe that demand grows at a constant rate. They believe that it depends on (1) real income and (2) relative price. Real income refers to Gross National Product (GNP) in constant dollars. Demand for food relates to real income. Another term is income elasticity which is:

$$\text{Income Elasticity} = \frac{\text{Growth rate of demand for commodity}}{\text{Growth rate of real income}}$$

Income elasticity for energy is about 0.8 and is a derived demand. With rising income, demands for services, which require less energy, rise.

Relative price is defined in several ways. One is the cost of living index - another is the GNP deflator.

$$\text{Relative price} = \frac{\text{Price of a particular commodity}}{\text{General price level}}$$

Price elasticity is a similar term to income elasticity and is defined as:

$$\text{Price elasticity} = \frac{\text{Growth rate of demand for a commodity}}{\text{Growth rate of relative price}}$$

and is usually a negative number.

Prices for oil and petroleum products dropped until last year. The effect was to accelerate the growth of demand for petroleum products during the periods from 1950 to 1970. We can distinguish between non durable and durable goods. With durable goods, long-run elasticity (income and price) is greater than short-run elasticity.

When gasoline prices rise, the short-run elasticity is relatively small. A long-run period for gasoline and electricity varies from 3 to 5 years. Electricity affects refrigerators, air conditioners and other related items.

The acceleration of demand for petroleum products placed a strain on supply. The Alaska pipeline was delayed because of the lower prices - and environmental questions.

The world petroleum market was dominated by seven oil companies, five of which were in the U.S., one in Britain, and one being British and Dutch. The major oil companies could not control companies like Occidental moving into Libya.

Current geological interests include the edge of the continental shelf. The North Sea has been explored for seven years and will be more important in 1980 than the Gulf of Mexico.

Reduction in crude oil prices created a lower profit for oil companies and the royalties for countries dropped. The Organization for Petroleum Exporting Countries (OPEC) formed a cartel to raise royalties. In Tehran, OPEC won a victory over the oil companies. At the 1971 meeting the U.S. Undersecretary of State made the unfortunate remark "Oil is our life blood." The U.S. was not equipped for a cartel by OPEC -- although the cartel by U.S. oil companies flourished in earlier years.

Until recently, (about 1950) the U.S. exported oil. The oil industry, during Eisenhower's administration, limited oil imports to 10% of domestic production. The U.S. was insulated from the world market to keep oil prices (and profits) up. Production was curtailed by pro-rationing in Texas and Louisiana. This kept U.S. prices about one dollar above world price levels. Production was kept lower in the U.S. until 1972.

Natural gas has been a problem in the U.S. because the Federal Power Commission (FPC) has held down the well-head price since 1950. The overall supply has thereby not kept pace with demand. Various means have been set up such as allowing domestic users a preference over industrial users - and intrastate perference over interstate users.

Coal resources are located in remote places like Wyoming, the Rocky Mountains, and related areas. Some coals are high sulfur, but the sources are close to industry. Western coal has less sulfur, but more water. This adds to the transportation cost. Rail transportation is the best means. Present plans indicate that existing facilities are more than adequate. A few bypass tracks are the only modifications necessary to ship coal. Strip mining would be used in Western states because the coal is near the surface. Reclamation is difficult because coal companies do not like to do it - and the rainfall rate is low. Arizona has been successful, so similar results should be achieved in Wyoming.

After one third of the oil in a well has been removed, the rest is left because of the cost of removal. With oil prices at $3 per barrel, very small secondary recovery was practiced. At $10 per barrel, more secondary recovery will be practiced. Secondary recovery equipment requires about a two year order-to-shipment period and steel shortages may extend this time. Steel capacity has not been expanded for 15 years and to increase steel pipe production steel sheet production must be reduced.

Supply and demand curves change with time. Data Resources Incorporated has studied this problem. The U.S. energy model (Jorgenson at Harvard) and the World petroleum model (Houthaker) are two current models to show this time variation. The high rate of growth of energy in 1960 was due to price, and the U.S. energy model permits a reduction in this rate. The world petroleum model covers (1) crude petroleum production, (2) transportation, (3) refining, and (4) consumption. Transportation and refining will move according to investment return. Production will rise with price.

FUTURE ENERGY SOURCES - COAL, NEAR TERM - SOLAR, FUTURE

Richard Greeley
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Dr. Greeley began his talk with a brief description of MITRE Corporation, which is a non-profit company which does consulting work only with government agencies. He then turned to the subject of his talk.

Coal

MITRE Corporation has a contract with the Department of the Interior, to see how coal production can be doubled or tripled by 1985. Consequently, they produced an overall projection of energy needs up to 1985. In general, Dr. Greeley believes that Project Independence by 1980 is impossible. Doubling coal production by 1985 probably is possible. Natural gas can be expanded rapidly, if deregulated.

The investment necessary to achieve projected coal production in 1985 is between $9.4 to $14.3 billion, plus an additional $6 billion in transportation.

Dr. Greeley then turned to the possibilities for increasing the supply of low sulfur coal supply. It should be pointed out that the potentials expected here are basically new mines. But some problems exist: the investments necessary are discouraged by present policy indecision, and environmental restrictions.

Congress has just given waivers for power plants to 1979, if high smokestacks are used, and if scrubbers are installed by 1979.

Solar Energy

Almost all of Dr. Greeley's discussion of solar energy is included in "Recommendation to RANN/NSF--Solar Energy R&T Program."

Mitre 300-watt, Solar Energy Demonstration System shows how solar silicon cells can be utilized in a complete system providing continuous output.

Cost of silicon transistors has decreased dramatically over the last 20 years. Dr. Greeley suggested that this same price decrease could occur in solar cells, leading to a cost, in 14 years of 50¢/watt, for production of electricity from solar cells. When pressed, he admitted that the cost of the total support system, including storage, etc., would likely boost this price significantly.

The Claude Ocean Thermal Differences Process indicates that a 10 megawatt power plant of this general type would require moving 2 million gallons of water per minute, assuming a 30°F temperature difference.

Dr. Greeley ended his discussion with the suggestion that our group might try to develop a good plan of how the U.S. emphasis on energy R&D should be placed--as opposed to present F.E.A. utilization of expected results per dollar expended.

ELECTRIC POWER-VIEWPOINT OF AN INVESTOR-OWNED UTILITY

Alan R. Barton
Senior Vice President and
S. Robert Hart, Jr.
Vice President-Engineering
Alabama Power Company
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Bob Hart: Background on Alabama Power Company (APC)

APC is a typical investor-owned power company and is one of several companies in the Southern Company system (a holding company).

Sources of APC Power (total generating capacity is approximately 6 GW):

Coal-fired plants	- 6 (80% of current output)
Hydro-power plants	- 13 (20% of current output)
Nuclear plant (1975-1977)	Planned Additions
Coal-fired plant (1978)	
Small hydro-power plant (1978)	
? (1981)	

Duplicate design concept is being employed in new plants to cut costs and to speed getting additions on-stream. From a safety standpoint redundancy of facilities in nuclear plants is emphasized.

All hydro-power plants on navigable rivers are licensed by FPC. The Federal government has takeover option at expiration of license and so far renewals have been on a year-to-year basis.

APC peak-load growth is running at 8-8.5% annual rate -- which is faster than national average. Seasonal patterns show pronounced peaks with air conditioning a significant factor.

Lead times:

Nuclear plants	10 years
Coal-fired plants	7-8 years
Hydro-power	?

Summer weekday hourly peaks run more than double minimum hourly demand. Hydro-power gives the flexibility to meet these fluctuations.

Power swapping between systems can solve some of the yearly peaking problems.

APC consumes approximately 50% of the state's coal output. Fifteen percent of Alabama coal is low-sulfur type. APC owns some coal reserves, but contracts out for coal production. APC is supporting some deep mine development in the state to acquire suitable low sulphur coal for new plants.

Alan Barton:

Power company charters require them to meet customer needs. The private utilities do not, therefore, feel they should allocate or ration electrical energy.

Utility pricing is coming under increasing scrutiny. Relating costs to customer class demand is used in formulating rates appropriate to customer classes. One apportioning basis is the fraction each class uses of peak power. High summer rates are used to help attenuate peaking. Wholesale rate increases are being sought by APC.

Fuel costs:	21% of revenue
Total operating expenses:	76% of revenue

Representative residential revenue situation:

1971	1.8¢/kWh
1974	2.1¢/kWh

Installed cost of recently-added coal-fired plant: $180/kW; $440/kW for nuclear; $300-350/kW for hydro. Advantage of nuclear plant is life-cycle fuel cost savings. Utilities constantly rollover their bonds, as a result higher interest rates have increased fixed charges.

Commitments to new energy generation technology is predicted on actual ability to meet demand increases as they arise.

APC's choice of nuclear site is based on demand growth pattern in area, lack of readily-available local fuel, and river proximity.

First-half 1974 demand up 3% over same period in 1973, expected 8% -- shortfall believed due to mild weather and user conservation of energy.

Voltage reduction does not seem an appropriate above-peak-load coping mechanism for APC. Cutting non-essential load is one way to share peak demand.

Architectural approaches to energy conservation seem to be gaining acceptance and are effective.

Overbuilding of capacity in viewed as not as critical as underbuilding.

Nuclear power additions will be confined to base-load capacity needs.

Must distinguish the concerned, willing-to-contribute environmentalists from those simply resistant to change.

Scrubber reliability (i.e., its low reliability) rather than cost is the factor limiting utility interest in scrubbers right now. Experimental use of various scrubber types continues, but solvent-refined coal appears to be a better approach at this time.

MAGNETOHYDRODYNAMICS

John B. Dicks
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University of Tennessee Space Institute
Tullahoma, Tennessee 37388

Mr. Dicks stated that the original theory of MHD conversion is attributed to Faraday. A gas is the best fluid because its thermal energy can be converted to kinetic energy by expanding. The kinetic energy is then converted to electrical energy. Liquids have been considered for MHD but they will expand very little so the conversion from thermal energy to electrical energy is less efficient. Gases, however, only conduct adequately if highly ionized, which occurs only at temperatures too high for compatibility with current materials. Therefore a small amount of "seed" (usually an alkali metal) is added to improve conductivity at moderate temperatures. Cesium seed gives very good conductivity but is too expensive for large scale use. Therefore potassium, which gives conductivities about half as great as does cesium, is being used.

Advantage of MHD: Nothing (like turbine blades) immersed in flow so higher temperatures are possible. Therefore greater overall conversion efficiencies are possible. (Cooling the walls is not difficult.) Goals: efficiency and simplicity.

Current MHD Research Activity

USSR - Using natural gas as fuel. (Expect to go to coal in 5 years). 20 MW design, but compressor seals feeding air to the combustor are limited.

to 3 atmospheres, which is too low to get 20 MW. Have gotten 7 MW to date and will probably get up to 11-12 MW. Maximum operating time to date about 24 hours, but hope to get 100 hours in next 6-9 months. Because of surface erosion, having problems with leakage of water used for wall cooling. Boiler tubes around exhaust generate steam for conventional steam-turbine bottoming cycle. About 1000 people working directly on MHD, 2500 total including those working on materials problems. Getting 99.8% potassium seed recovery. Could probably solve compressor problem by using liquid oxygen.

US - Working on coal as fuel because of expected abundance. Use potassium seed. K reacts with SO_2 to give K_2SO_4 so that there is little SO_2 left in exhaust. K_2SO_4 is easily removed which solves SO_2 pollution problem with coal. K^+ does tend to accumulate slightly on electrode. Ideal amount K is 4-7%, but usually less than 1% is used because of seed recovery economics.

At the Space Institute Dr. Dicks is seeking a 50-55% overall efficiency.

Development Plan

Year	73	74	75	76	77	78	
Million $	3.0	7.5	12.5	28	52	53	etc.

Funding will taper off to 1986 with a demonstration model online about 1983. Evaluation of the demonstration model to be completed by 1986.

Total program cost thru 1986	$560 million
Less sales of power	- 150 million
Net investment in MHD	$410 million

The schedule could be compressed but this is probably not necessary. About 1986 is when MHD will be needed. Coal gasification won't be economic until 1986 or after. Some estimates for coal gasification are about $1/ million BTU. This is higher than projected costs for imported gas.

Large power plants have many outages, so MHD is not expected to be different in that regard. MHD plants will be best if large because losses to collector cooling water go to a few percent at large size. An MHD plant will be more compact than a conventional plant.

TECHNOLOGY ASSESSMENT

Joseph F. Coates
Project Manager
Office of Exploratory Research and Problem Assessment
National Science Foundation
Washington, D. C.

Dr. Coates said that technology assessment may be considered as a policy study in valuing such topics as the economy, environment, family institutions, etc. The results of the study can be put into the hands of decision makers.

When considering technology assessment from the point of view of the engineer, we think of systems analysis, engineering design, etc., - most engineers work along these lines to explore the full range of complications and their effects upon man and his activities.

We must always consider the adequacy of methods of controlling technology or assessing its impacts on society. The implications of technology may be how to manage and this may be further dependent on the events to follow. For example the "Pill" was not always available. Clearly the "Pill" worked as nothing else worked in the past and with extreme safety. This technique allowed women to enter the work force more than otherwise. Failure to look at the technology involved in the "Pill" caused housing and population problems in a 10-20 year period.

Always be sure of the difference between a problem and an issue. The problem of crime on the street is no problem. It is more likely an issue involving public policy. To avoid crime on the streets people need to make wiser decisions.

Bureaucracies fear technology assessments because they represent a threat. Bureaucratic managements do not like to have their assumptions found in error. This may result in loss of employees which may be followed by a reduced budget.

An important consideration in technology assessment is that sophistication is irreversible. Best to remember that an assessment is an ART form. Let us look at the art form model.

Assessment of technology can be the solution to many of our problems. Let us try them.

There are ten modules to be considered in the assessment of technology. They are:

What is the problem? Knowledge of this may be lacking.
What are the systems that should be implemented?

What are the impacts involved?
Which of the impacts are serious?
Identify decision makers. Who is in charge?
Determine the options available - the creative part.
Conclusions and recommendations. All should involve an analysis with consideration of the consequences.
Identification of parties involved in a study.
Consider macro alternatives. These should provide a standard for evaluating tradeoffs.
Identify exogenous variables. This is most critical. For example, the Arabs and the Energy Forecasts, 1965-1973.

ENERGY ASSESSMENT

Ron Larson
Office of Technology Assessment
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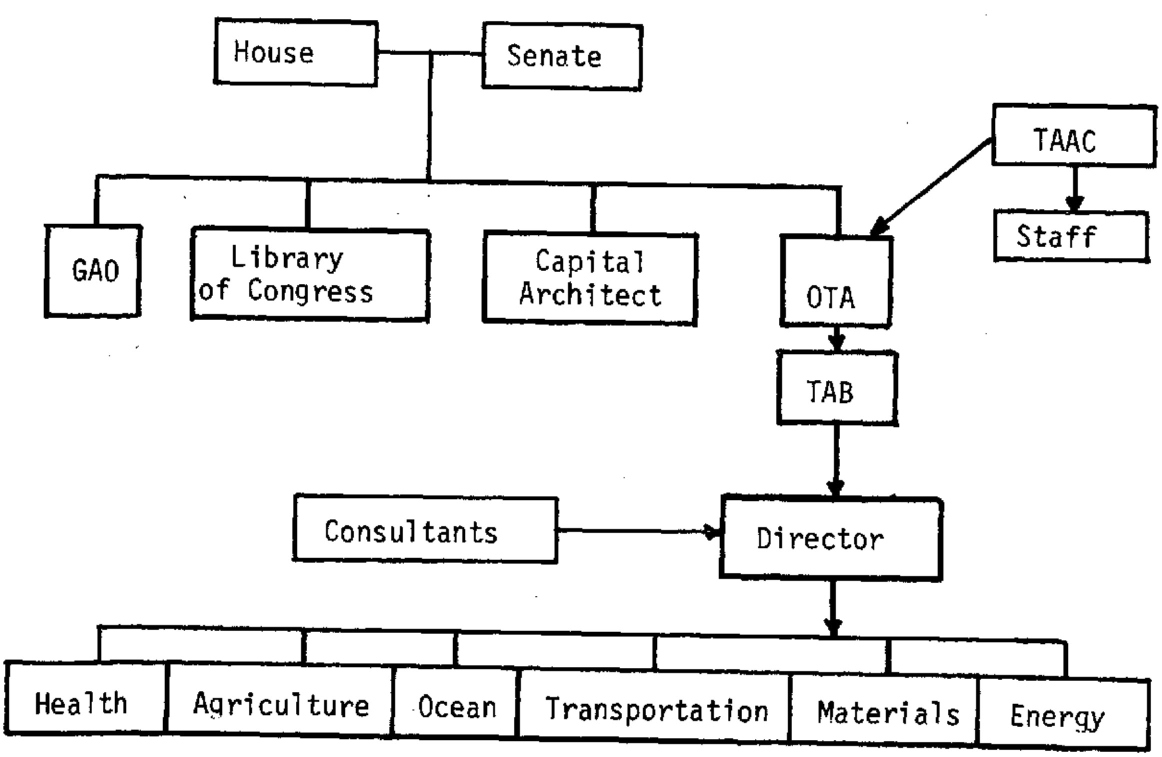
Washington, D. C. 20510

Dr. Larson has worked primarily with Mike McCormack, the Chairman of the House subcommittee on Energy, which sits under the House Science and Astronautics Committee, Olin Teague, chairman. Though McCormack is only in his second term he has this position for he is one of the very few members of Congress with technical background (M.S. in chemistry, university and industrial nuclear research) and his staff director is Tom Ratchford, a physics Ph.D.

A bill, HR 11864, that Dr. Larson helped write has passed the House and Senate and is now being revised in joint hearings. The administration opposes this bill. The reasons for their opposition and the history of the bill are interesting. In the fall of 1973 solar energy demonstration bills were introduced in the House and Senate; HR 11864 being the House bill. It passed by a large majority and was sent to the Senate where a record five committees held hearings on it. The bill went initially to the Senate Aeronautical and Space Sciences Committee (Frank Moss, Chairman), was modified and finally was reported out in further modified form by the Labor and Banking Committees. The modified bill passed unanimously in the Senate, and is now being put in final form. It will probably become law even though the Administration opposed it. The reason for this opposition is that it is a demonstration bill and does not involve basic or applied research into solar energy. As such it falls outside the charter of NSF, which presently dominates solar energy research activity. But more than NSF is involved here, for it was OMB that decided to put solar energy research all into NSF, so OMB opposes them also. There are less political reasons for the opposition also. The House bill takes the position that solar energy technology is essentially

here now, NSF (and OMB) act as if the technology is not available now, but that given a few more years, NSF sponsored research will make it available. This is a somewhat odd stance since the actions under the bill will not begin for a couple of years anyway and by that time all solar energy work may well have shifted to ERDA. At its top levels ERDA will probably be dominated by the AEC (which incidentally is scheduled to split soon into a research wing, ERDA, and a regulary wing, NEC). The AEC has a solar research budget of $600,000; the program is headed by Jim Rannels. Thus it is not clear what sort of effort in solar energy would be made by ERDA. [Larson noted that the most knowledgeable people in Congress; e.g., Udall and McCormack, oppose ERDA. The reasons are that weapons research will probably be included so that the financial pie may not have a sufficient piece for non-military work, and that FEA and ERDA seem to have no administrative relationship. FEA is primarily concerned with Project Independence, though Alvin Weinberg is involved in some research. There is some possibility of creating a new department, DENR, overseeing both FEA and ERDA.]

Dr. Larson is working with OTA for the next year. OTA was funded in 1973 after six years of effort by E.A. Daddario. The organizational chart looks like this:



TAAC - Technological Assessment Advisory Board; Harrison Brown, Jerome Weisner... The staff consists of Buford Macklin and several AAAS Fellows.

TAB - Technological Assessment Board - 6 Democrats, 6 Republicans, with 3 of each Party from each House. Senator Kennedy is currently chairman.

Consultant - Dave Rose, MIT

OTA is an audience for our report because OTA needs an in-house capability for energy policy assessment. According to David Rose, OTA continually is asked questions by Congress about policy impacts; e.g., effect of tax credits for solar heating. OTA has only three ways to go: (1) outside contractors - this buys believability (2) National Academies - historically they serve the executive (3) In-house - but staff is insufficient. Further, energy policy is fragmented, so any report that looks at many aspects of energy policy would be important.

POWER SYSTEMS AND THE ENVIRONMENT

Dennis J. Cannon
Technology Transfer
Office of Research and Development
Environmental Protection Agency
Washington, D. C. 20460

EPA was formed in 1970 under the Public Health administration. Its functions regarding power are research and standards on air and water quality.

The SO_2 Problem

Plants burning high sulfur coal must install scrubbers. The cost of SO_2 removal equipment, operation, maintainence is 10% of the capital cost of the plant and 5% of the total operating cost.

The NO_x (nitrogen oxides) Problems

Mr. Cannon admitted that the pollutant nature of NO_x's was uncertain, that air traffic enhanced NO_x in the air, but that EPA had the least handle on it and that it was their most controversial problem. Should NO_x be proven non-toxic EPA might be liable in the courts.

How EPA sets Standards

Pro

EPA meets with power people to find out what has been done, what's achievable with some effort, and what the technology is. The emphasis is upon the technology. (Power plants usually hire consultants to operate the technology because they don't have the technical people.) Looking at air-water quality requires knowing who's causing what and this is often difficult to determine.

The effects of pollutants on health is being researched. EPA's philosophy is to limit now if there's any indication of a problem.

Standards are also based on air quality. There is a national pattern. States determine actual limits. Philosophy is non-degradation.

Con

Emphasis should be on what's acceptable. Level of pollutants should be required to be below what is necessary to insure health.

There's no good experimental evidence to prove that certain things are harmful.

Non-degradation means no detectable deterioration. Detection gets better as measurement instrumentation improves.

How much sulfur or any "pollutant" needs to be removed; can be removed? Cannon admitted that geography plus power density may make it impossible to remove, even with low S coal and scrubbers, the amount EPA would like.

A national direction by EPA is reasonable; regional offices work with the states, who set the controls; national and state responsibilities and authorities are pretty equal, eventually states will take over full responsibility.

We use 8% of the flyash in construction - sludge mix with concrete- whereas Europe uses 40%.

Cooling towers are required of every base loaded power plant unless they can prove they're not needed.

NBC WHITE PAPER (ENERGY)

We are presently using each year about 2 billion barrels more oil than we are producing and it is expected that imports may rise to 50 percent by 1980.

Indications are that one-half of the oil present in the United States has not yet been discovered. However, wildcatters, who have found about 85 percent of the producing wells in the U.S., are becoming more and more scarce. Another consideration is that producing wells in the U.S. have dwindling productive capabilities - example of 50 barrels/day wells that now produce 10 barrels/day.

Looking at the gas picture, the shortage of gas has been and will continue to be a real problem. The situation in Louisiana during the winter was examined in terms of the availability of gas in the area of production as opposed to its availability on the Northeast coast to which the pipelines delivered Louisiana gas. There was quite a difference of opinions about who should have the gas derricks on their shore lines to provide the much needed gas.

A discussion of the position taken by gas companies on price regulation by the government was presented. They believe that the artifically low prices of gas have stifled further explorations.

OFFSHORE NUCLEAR POWER SYSTEMS

Larry Musselman
Senior Project Engineer - Marketing Department
Offshore Power Systems
8000 Arlington Expressway
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The concept of offshore siting of nuclear power plants (the floating nuclear plant or FNP) is a joint venture of Westinghouse and Tenneco. This venture attempts to combine proven technologies for a new application.

The joint venture was formalized into Offshore Power Systems in July 1972 and now has contracts for delivery of two of these FNP to Public Service Electric and Gas Co. of New Jersey. The first unit is scheduled for delivery in July of 1979. In addition, Japan, Northern Europe and some Carribean Countries have indicated an interest in these plants. Roughly 42% of today's total U. S. demand for electrical energy exists within a 200 mile strip along the Atlantic, Gulf and Pacific coasts. Thus offshore nuclear plants provide a good way to meet these needs.

The major characteristics for FNP are as follows:

Width, Ft.	378
Length, Ft.	400
Height above water, Ft.	177
Displacement, Ton	160,000
Draft, Ft.	32
Net Output, MWe	1,150
Transmission Voltage kV	345
Reactor Rating, MWt	3,425
Seawater cooling (gpm)	900,000
Crew	125
Life (years)	40
Cost (per unit)	$400,000,000

The first of these plants will be constructed at a special site in Jacksonville, Fla. (Blunt Island). Here the units will be assembled using many streamlined techniques for power plant production. Once the units are complete they will be pulled to their sites by six tugs where fuel will be delivered. The total trip time to Boston would be about 11 days. During the pull to their site these plants move a a speed of 2 knots and are somewhat vulnerable to bad weather since there is no "safe port" along the way.

The on-site environmental considerations are as follows:

Safe for 26 ft. tide
Safe for 180 MPH hurricane
Safe for 300 MPH tornado
Safe for 0.3g seismic shock
Ocean temperature rise of 17 degrees F at exit
Thermal effect area of 5-7 acres
Intake water velocity at protective screen of 1 ft/sec.

A completely new shipyard facility is being constructed at Jacksonville, Fla. capable of making 4 plants per year with about 2 years required from start to finish on a unit. Because of the assembly-line conditions, productivity will be higher, standardization and quality control more effective and the uncertainties of field construction can be minimized.

U.S. ENERGY PLAN

Richard Pastore
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Mr. Pastore was the Staff Director of the report "The Nation's Energy Future" prepared by the AEC for the President. This report was the result of a request in a Presidential speech on 29 June 1973. The purpose was to develop a R/D plan for this country for the next 5 years starting in FY 75 with a budget of approximately $\$10 \times 10^4$. They sent out a RFP requesting ideas on what would be possible in R/D in the next 5 years and received 1105 answers ranging from new pump design to end product pricing to the orbiting solar station. These proposals totaled $\$25 \times 10^9$. To evaluate the proposals 16 panels of government employees were set up as it would have taken too long to use outside consulting firms. The 16 panel areas were: resource exploration and assessment; mining; coal conversion; energy conversion systems: turbines, fission, fusion, solar; geothermal; systems analysis; oil and gas; environment; basic research; advanced transportation systems; fuel and energy transmission; conservation. EPA and Interior had a member on almost every panel because of their wide interests.

The final report was divided into five areas: conservation, increase in oil and gas production, substitution of coal, validation of nuclear, and exploitation of renewable resources. The validity of nuclear can only be judged after additional time although at present the validity seems good.

The recommend funding level and the percentage of increase in the above categories compared to FY 73-75 are:

Conservation	$\$1.4 \times 10^9$	215%
Oil and gas	0.5×10^9	159%
Substitution	2.2×10^9	356%
Nuclear	4.1×10^9	85%
Renewable resources	1.8×10^9	162%

The "Nation's Energy Future" is not a very good national energy planning document. It is good on delineating the issues and technical constraints and potentials, but alternative plans were not evaluated.

The breeder is safer than the BWR even for a coolant accident. A BWR loses all the water in a break, but sodium doesn't flash to steam so it stays around. Breeders are designed so they can't go supercritical. The breeder has been shown to work, but the problem is the long fuel doubling time, which at present is 25-30 years.

AEC has just let a contract to S. M. Stoler Co. to study the breeder fuel cycle. The shortage of uranium reserves is a problem. The U.S. will need 14,000 tons of yellow cake to feed the enrichment plants by 1982. There is a question of our ability to do this. Foreign sources are not too promising since they use about all they produce. There are presently restrictions on importing uranium, but they will be lifted by 1982. However, there probably won't be anything to import. Uranium mining is comparable to gold mining in difficulty.

Waste material storage

The AEC policy is to put waste into temporary storage until a long range solution can be found. There is no alternative to this strategy. The AEC is designing surface retrievable storage for high level wastes. A user can store the waste material as a liquid for 5 years, but then must deliver it dry to the AEC at the end of 10 years. The best approach now is to store the solid waste in stainless steel canisters inside carbon steel inside cement and then put in the desert. This is supposed to protect the environment from the waste for 100 years. Cesium and strontium have half lives of about 30 years. There is, however, some plutonium in the waste which they will try to take out before storage. If this can be done, the waste will be down 10 half-lives in 300 years and should be fairly safe by then.

The government provides the storage facility, but the reprocessor pays other costs.

There is not a lot of high level waste. There is more of a problem with middle level and low level trash. Breeders would cut down on the waste problem since they could burn actinides to shorter lived products. So far most of the waste has been generated by the government. The scope of everything is getting larger and we must have faith that technology will solve the problem. Waste is not an ever increasing problem since we will have fusion and solar by 2050. However, the AEC is not lightly dismissing the problem and has a large R/D program concerning waste. Most of the present solutions are technically, but not economically feasible. The public does have a choice. They can wait if they're willing to stop using more energy. Storage costs will be about .1 mil/kWh. There are now 3 reprocessing plants, but none of them are presently operating. A surface storage area of about 2 sq. miles will be needed by the year 2000.

BREEDER REACTORS

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One reason for the increasing emphasis on nuclear power is our current energy crunch. If 700,000 megawatts of nuclear power were put into operation by the end of 1990 rather than the currently planned 500,000, fossil fuel savings would be equivalent to 6-1/4 million barrels of oil per day or 49 billion barrels of oil over the lifetime of those plants. 49 Billion barrels of oil is 25 percent more than the proven oil reserves in the United States.

Another factor is the economics of nuclear plants; although capital costs are greater than for fossil fuel units, fuel costs over the lifetime of the plant favor the nuclear unit.

The 1973 fuel costs per kilowatt-hour were 2.1 mills for nuclear. 3.6 mills for coal, and 6.6 mills for oil. Current forecasts for 1979 in escalated dollars are 2.0 mills for nuclear, 5.3 mills for coal, and 9.8 mills for oil.

Not all reactor concepts require the same fuel cycle. Some heavy-water moderated reactors are fueled with natural uranium requiring no isotopic enrichment, recovery, or recycle of spent fuel. Some water-cooled reactors may use plutonium as well as uranium 235 for the fissile material in reload cores (the second and subsequent fuel cores). At the present time the slightly enriched uranium-fueled water-cooled reactor is the system predominantly used throughout the world.

The nuclear fuel cycle begins in a uranium mine such as Utah International's Lucky McMine in Fremont County, Wyoming, one of the larger mines in this country. Uranium occurs in nature in the form U_3O_8. Ore assays vary typically run about 3/10 of one percent U_3O_8 by weight.

Uranium ore is transported to a nearby mill where the U_3O_8 is separated from the other ore components. There are approximately 20 such mills in the United States, most of which are located in the Rocky Mountain states near the principal ore producing localities. Mill concentrations are 70 to 90% U_3O_8. These concentrates are usually yellow giving rise to the common name "yellow cake".

The United States demand for U_3O_8 will increase over the next decade as new reactors go on line. Based upon recent AEC forecasts, annual requirements will increase from 11,000 tons of U_3O_8 in 1973 to 58,000 tons in 1983. Current production is 13,000 to 14,000 tons per year, expandable to 22,000 tons per year with full utilization of existing production facilities. Based upon this forecast, additional milling facilities will be required by 1977 to meet projected demand. Known domestic U_3O_8 reserves recoverable up to $8.00/lb forward cost are estimated at about 270,000 tons.

About 70,000 tons more are estimated to be recoverable at $8 to $10/lb forward cost. Based on the current tails enrichment and neglecting the impact of recycled material, these reserves would satisfy industry requirements until the early 1980's. This suggests that higher ore prices can be expected.

The next step in the fuel cycle is conversion of the ore concentrate to uranium-hexafluoride, UF_6, required for isotopic separation. Allied Chemical's conversion facility in Metropolis, Illinois is one of three such facilities now in the United States and Canada. The conversion process concentrates U_3O_8 with cracked ammonia to reduce these higher oxides to UO_2. The UO_2 is then reacted with anhydrous fluoride to form UF_4 or "green salt". Fluroine gas treatment then forms crude UF_6 which is purified in distillation columns to produce the pure UF_6 required as feed material to the enrichment plants.

In its natural form uranium contains only 0.711 weight percent of the fissile isotope U-235. By contrast, light water reactors require enrichments of this isotope of 2% to 3% or more. Currently, the AEC operates enrichment facilities at Portsmouth, Ohio, Paducah, Kentucky, and Oak Ridge, Tennessee. The process at each facility is based upon gaseous diffusion. In a diffusion cascade UF_6 is pumped through a series of porous barriers which separate the UF_6 into enriched and depleted streams. Many states of operation are required to produce 2 to 3 percent product enrichments. A one gigawatt light water plant has an annual fuel cycle cost of approximately $12 million, of which $3 million represents enrichment cost. With light water plants worldwide the enrichment becomes a large market in the 1980's.

Following enrichment, the UF_6 is shipped to fuel fabrication facilities such as General Electric's Plant in Wilmington, North Carolina, currently designed for approximately two million pounds of uranium per year as fabricated fuel assemblies. This is equivalent to eight 1 GW first cores per year. The enriched UF_6 is converted to uranium dioxide. This is pressed into pellets, sintered and loaded into zirconium tubes. These loaded tubes are assembled with other hardware to form a finished fuel bundle.

The fuel bundles are shipped to a reactor site and loaded into a reactor. Over three to five years the fission process generates heat and reduces the U-235 concentration. At discharge from a reactor a fuel bundle has considerable residual worth. The spent fuel is then shipped to a fuel recovery plant.

One fuel recovery plant is General Electric's Midwest Fuel Recovery Plant (MFRP) in Morris, Illinois. This plant will have an initial capacity of 300 million tons per year of spent fuel. At the MFRP the remaining uranium and plutonium and neptunium generated during reactor operation are chemically separated from the radioactive waste products by a remote, shielded operation. Uranium is recovered as UF_6 for return to the AEC enriching plant. Plutonium and neptunium are recovered as aqueous nitrate solutions. Temporary storage for the radioactive waste is provided at MFRP (these wastes will eventually be placed in permanent AEC storage). The recovered plutonium and uranium can be returned to the fuel cycle. The neptunium isotope is utilized for outside applications.

A recent survey of the National Association of Electrical Manufacturers indicates that nuclear plant additions will surpass fossil in 1980 for the first time in the history of the industry. The Atomic Industrial Forum has concluded that it is feasible to add 200 gigawatts to the 500 gigawatts forecast for year-end 1990. But William E. Simon, when he was head of the Federal Energy Office, told the Joint Committee that nuclear additions must be increased in 1990 to eight times our present capacity.

ENERGY FROM COAL

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Why should the United States be interested in coal instead of the other forms of energy supply? The U.S. has proven reserves of 300 billion tons of coal at depths of 3000 feet or less. Of this quantity, approximately 2000 billion tons are recoverable. Approximately 40% of this supply lies in the Fort Union deposit.

In coal gasification, it is possible to obtain 16,000 cubic feet per ton of coal, resulting in a total supply of 32,000 trillion cubic feet. There are only 1,600 trillion cubic feet of petroleum gas, therefore coal gas would provide about 20 times the proven gas supply of the world.

If the U.S. energy supply was based on coal with a 70% conversion efficiency and combined with projected U.S. energy usage rate in 1980, the U.S. coal supplies would last approximately 200 years. Therefore, there is no need for a crash program for the development of other energy sources.

A well operated big mine in the early 1960's was capable of running 80% recovery. For a seam 5 feet thick, there should be 10,000 tons/acre. The recovery rate is still 80%, however, the average for poorer mines is on the order of 50-60%. Therefore a recovery rate of 66% would be a good average.

The amount of manpower required to mine coal is substantially greater than for oil, gas and uranium. In 1948, the coal industry mined 628 million tons of coal with 600,000 miners. Today, we mine 600,000 tons of coal with only about 100,000 miners. We used to mine 38 tons per man-shift. Due to safety requirements, the rate has dropped to 25 tons/man-shift; however, this rate is rising due to improved mining methods.

In 1944, the government authorized an $850 million synthetic oil facility in a coal area. Germany also had coal oil facilities producing gasolines, some up to 100,000 gallons/day. These plants planned for the U.S. might be able to produce gasoline at 2¢ gallon, with by-products of benzene, toluene, and others.

In 1961, the Office of Coal Research was formed with an initial budget of $1.0 million. A few years ago, the budget was $45 million. Starting Fiscal year 1975, the budget is $275 million. The objectives of the Office of Coal Research are to investigate the means for conversion of coal to power, synthetic gas and synthetic oil. There is not much emphasis on by-products.

There do not appear to be any stack gas scrubbers that perform as planned. It would be better to take the sulfur out of the coal rather than SO_2 out of the stack gas. There are millions of cubic feet of stack gas per minute which makes it extremely expensive to scrub gas.

Coal mines operate 15 shifts/week, yet coal is only mined 10 shifts/week. The coal output could be doubled, with perhaps only a slight addition of equipment. Coal production could be expanded if there were more miners, more man-power and equipment. There are a few mines which operate 21 shifts/week without difficulty.

To set up a coal mine operation requires millions of dollars, and return on the investment will not come for at least 20 years or more. Chemical process payback periods may be 10 years, and pharmaceutical payback periods are about 5 years.

A Fisher-Tropsch Plant at 115,000 tons coal/day at $9.00/ton will yield 100,000 barrels/day of oil and 1.67×10^9 cu ft/day of gas. The cost would be 1.7 billion dollars with a rate of $1.20-1.25/million BTU (1973 dollars).

Some coal operations mix good water with coal to make a slurry and pump it hundreds of miles. It should be pointed out that some western coal is 40% moisture.

Strip mines are less than 300 ft in depth. Most underground mines are less than 1000 feet, with some special coals at 2000 ft. Eastern coal is 25×10^6 Btu/ton and western coal is 13×10^6 Btu/ton. It should be pointed out that 40% of the U.S. coal is strip-mineable.

The time table for a coal gasification plant would be to start construction now (1974), check out in 1978, with production in 1979-1980. The main bottleneck would be in the area of technical manpower. The construction and engineering manpower required would be on the order of 4000 per plant. The environmental impact statement is the delaying factor at the moment. Current petroleum imports are 1.5 billion barrels/day therefore there would be a need for about 10-15 plants in order to meet the need by 1990.

THE NUCLEAR ELECTRIC ECONOMY

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Dr. Creagan stressed the following points during his seminar presentation.

The basic existence of an energy crisis was pinpointed by the Arab embargo. We must utilize our large reserves of coal and nuclear energy.

While conservation will ease the demand for energy it will not be sufficient to meet the energy crisis. We must explore other modes of supply and use synthetic fuels. Coal must be substituted for gas and oil where possible. The nuclear electric economy can pick up a very large part of the market for power. Our productivity of goods is highly dependent on our energy supply.

Electric cars will need an expanded electric supply. Large furnaces in industry can be fueled by electricity rather than oil or gas.

When industrialists confer, they must assure the Federal Government that they are not violating anti-trust laws.

The present AEC limit on individual nuclear units is 1300 MW. Cooling requirements heavily influence siting. Future plans are for building 4 gigawatt units.

Even today, steel for construction is in short supply. Competition is keen between oil interests and electric power interests for steel. Labor costs have escalated so that field construction is becoming prohibitive. Packaged units are shipped, ready to run, from the factory.

Heat pumps have been advocated for home and apartment heating but reliability has been a problem. Today's high reliability heat pumps have a coefficient of performance of 3.

Burning natural gas in a home furnace results in less than 50% efficiency (2.2 to 1 BTU ratio).

Using Nuclear Fuel at the electric power plant and a heat pump in a home results in a 1.6 to 1 BTU ratio, which represents an efficiency of 62%.

We must not allow ourselves to be vulnerable to the vagaries of the world oil market. Our economy must not be jeopardized by the manipulation of foreign powers.

The Gulf Gas-Cooled Reactor compared to the BWR theoretically looks good but there are problems. Thermal cycling problems are significant. The rest of the nuclear plant industry is watching Gulf's progress with some interest. They are expending a great deal of money to develop this concept.

The CANDU reactor which uses D_2O rather than H_2O presents additional problems over the BWR or PWR. Capital expenditures are greater. The market for Canadian nuclear power plants may be very good due to the fact that a buyer would be independent of U.S. diffusion plants and non-proliferation treaties.

THE BROWNS FERRY NUCLEAR POWER PLANT

Robert Metke
Engineering Department
Browns Ferry Electric Generating Plant
Athens, Alabama

Fuel: Uranium Dioxide in pellet form. Each pellet (2.19% average enrichment) is equivalent to about two tons of coal from an energy standpoint. (This figure includes the reprocessing cycle.) Total core requirement is 186 tons UO_2 which includes about 4 tons of U_{235}. Fuel is arranged into 76 bundles, 49 tubes/bundle, 192 pellets/tube. The tubes also contain varying amounts of Gadolinium for flux flattening through the core. The control rods, one for each four fuel bundles are of boron carbide. Control rod speed is limited to 3 feet/sec. The reactor core contains many small fission chambers to monitor reactivity throughout the core.

Operating Conditions: Water (steam) is the coolant and operates at 950 psi and 546°F. At the steam outlet the moisture content is 0.3%. During steady state conditions, 14 million pounds of water/steam per hour are circulated. The steam drives one high pressure and then three low pressure turbines on a single 222 foot shaft which drives a hydrogen-cooled generator. The reactor vessel weighs 624 tons, is 22 feet in diameter and 75 feet high. Each reactor is capable of generating 3293 MW thermal power which is converted to 1152 MW electric power. Thus the entire plant (3 units) will be capable of generating 3456 MW electric power when completed. At present, 4400 cubic feet per second (10 percent of the Tennessee River) is used to cool the single reactor/turbine plant. Cooling towers are under construction which will greatly reduce river use. There are nine air monitors surrounding the plant at various distances out to 45 miles which monitor particulate and iodine amounts and other gross activity. This data is continuously telemetered back to the plant. Six 500 kV transmission lines carry the energy to various TVA load centers.

LEGISLATION AND ENGINEERING MANPOWER

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Mr. Miller began his discussion of manpower by relating his experience at a socio-economic conference on engineering manpower sponsored by the I.E.E.E. (Institute of Electrical and Electronic Engineers). Mr. Miller concluded from his experience at that conference that there is inadequate information to: (1) define who are engineers, (2) determine the present number of engineers, (3) determine the production of engineers and, (4) to assess the application of engineering manpower.

The result of the conference was that the I.E.E.E. requested the A.C.E. (Association for Cooperation in Engineering) to spearhead some reliable studies of engineering manpower requirements for the future in light of the "Energy Crisis."

There is a need for information about legislation that concerns the engineer and engineering. In an effort to meet those needs the A.S.M.E. and the I.E.E.E. jointly published Legislation of Interest to Engineers. This publication is an effort to inform engineers on the purpose, status, and backing of legislation that may affect engineers and engineering.

As part of his discussion of legislation Mr. Miller noted that much proposed legislation is intended to raise interest and response from congressmen and interested parties outside of Congress and is not intended for passage or enactment. Mr. Miller emphasized that there was no single agency to coordinate energy R&D efforts and this often results in confusion and mismanagement of R&D expenditures.

Mr. Miller stated that one goal of his office was to represent engineers and engineering in Washington. He noted that as part of this effort A.S.M.E. was supporting moves by professional engineering to unify on major issues.

ELECTRIC CARS

Ernst S. Stuhlinger
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Marshall Space Flight Center, Alabama

Dr. Stuhlinger represented himself as a private citizen, not a member of MSFC in this presentation. He advanced the suggestion of a COMmuter CAR (Comcar) as a partial solution to the energy situation. A summary of his talk follows.

The proposal to power an automobile with electric energy from batteries is not new. In fact, electric cars have been around even before the gasoline-powered automobile was invented. However, there are several reasons why the revival of the electric car idea appears to be warranted at the present time.

First, the electric car as proposed here would be designed and used for a very specific application, for commuter traffic between home and work, and between home and mass transit stations. The volume of this kind of personal traffic has increased significantly during recent years. Second, acceptance of an electric car for commuter traffic would drastically reduce gasoline consumption and air pollution. Third, the electric car, as proposed here, would significantly reduce problems of traffic congestion, traffic noise, and city parking. Fourth, considerable progress has been achieved during recent years (mainly through the development of space flight technologies) in light-weight, high-efficiency, high-reliability electric components, particularly batteries, motors, and solid state cirucits for control and charging. Electric cars incorporating this technological progress would not have many of the shortcomings of those electric cars which were built in the past.

The following features are typical of a "commuter traffic situation" in many cities:

Short periods of driving (less than 1 hour) in the morning and in the evening, with long rest periods (8 to 14 hours) between driving periods.

Moderate distances to be covered during each driving period (always less than 50 miles; mostly less than 25 miles).

Moderate speeds (mostly less than 45 miles per hour, rarely more than 50 miles per hour).

Occupancy mostly 1 person per car, rarely 2, very seldom more.

Large size cars and overdimensioned engines.

High rate of gasoline consumption.

High rate of pollutant generation in city traffic.

Congested traffic conditions and parking lots, aggravated by large sizes of most cars.

Considerable noise generation because of frequent stops and starts.

It is obvious that the large, gasoline-powered automobile is not the ideal vehicle; instead, a small, non-polluting vehicle which does not consume gasoline would be preferable. The electrically powered commuter car (Comcar) may be a solution for this need. The Comcar would be used for commuting between residence and work, schools, shopping centers or airports. It would also be used in a "composite" traffic pattern involving a fast mass transit link between cities or between a city and a distant residential area. In this case, a person who commutes regularly though the mass transit system may own two Comcars, and use one at each terminal of the fast mass transit link. Pooling by two Comcar owners would also be a possibility in this case.

The Comcar would be small and would accomodate two adult persons, or one adult and two children. The motor of the Comcar would develop about 20 horsepower, equivalent to 15 kilowatt. Maximum speed would be 50 to 60 miles per hour. With a fully charged battery, the car could travel up to 100 or 150 miles before recharging. Parking lots would be equipped with "hitching posts", carrying power outlets (230 volts, 60 amps, a-c) into which the charging cable of a Comcar can be plugged for recharging during parking, for about 1¢ per kilowatt-hour. A complete charge through power outlets will require 3 to 4 hours. Charging through standard 110 volt outlets can be achieved at a lower charging rate and a charging time of 5 to 10 hours.

Introduction of 40,000 or 50,000 electric Comcars in a city of 180,000 people would increase the city's total consumption of electric energy by about 30%. It may be argued that even electric automobiles are not pollution-free, because electric energy to charge the batteries must be generated in power plants that produce pollution. However, total pollution connected with the operation of an electric car is still far below the pollution produced by today's gasoline cars for the following reasons:

> A significant portion of our electric power is generated by hydro-electric and by nuclear-electric plants. This portion, relative to the portion produced by oil and coal burning plants, is increasing rapidly.
>
> Oil and coal burning powerplants work with higher conversion efficiency, and with better pollution control systems, than gasoline-powered cars.
>
> The electric commuter car will be powered with a 20-horsepower engine, as contrasted to the 200-plus horsepower engines of many gasoline-driven automobiles.
>
> Electric cars will not idle their engines during traffic stops, loading and unloading, and warm-up periods.

THE ELECTRIC UTILITY INDUSTRY IN FRANCE

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FRANCE

The first topic Mr. Simon discussed was the make up and plans for the national electrical transmission grid and its associated industry.

France needs considerable transmission capacity since suitable power plant sites are concentrated in the coastal zone. There is not a surplus of river cooling water inland.

R/D on the upgrading of transmission line capability is important. It is necessary for France's export industry that its equipment be competitive. Studies are underway on scaling problems and reliability in upgrading existing lines from 220kV to 400kV. Little difficulty is seen in accomplishing this step. Joint studies with Italy are examining the design of 1200kV lines. Some problem areas are: reduction of line-to-line spacing to reduce right-of-way requirements without reducing reliability; critically examining present coefficients of safety to pare them down to the necessary levels; improved insulation design; research on positive phase switching; and developing testing facilities for UHV equipment, which is extraordinary in size and cost and in operation costs.

A decision based on Government policy more than technological merit has been reached to install no D. C. transmission lines. Germany is working hard on D. C. technology. Some advantages of D. C. are lack of phase problems, some cost benefit at long distances and some benefit as a tie in between two ac grids.

Two major undersea lines between England to France and Denmark to Sweden are in operation.

Currently, France has about 33 GW of peak electrical capacity with almost equal division among coal, nuclear, hydro. Nuclear capacity has been contracted at a rate of 6 to 8 GW per year. Plants are turn-key light water PWR and BWR. Installation rate is limited only by plant suppliers capacity. France's national policy includes self sufficiency and no growth of energy use this year with 10% reductions in end use, installation of nuclear power as fast as possible, beginning a 3% energy growth from 1976 until 2000 with mostly nuclear installations providing the increased capacity, holding fossil imports steady until 1990 (no growth) and then phasing out fossil imports.

A real shortage of capital exists; there is simply no cash available; there are banking problems, and a real reluctance to invest.

France is benefitting from the North Sea oil and gas fields but the North Sea oil and gas is the salvation of England.

France has good relations in Africa and development has been pushed strongly since DeGaulle. He sees few political problems in Africa.

The United States is the only country technologically strong enough to lead much needed development worldwide. For this reason, it is expedient for everyone to keep the U.S. strong. Examples of worldwide development which is needed is the exploitation of Brazil (for Brazil) and Siberia (for Russia). Russia needs U. S. dollars to buy U.S. technology. Any nation needs large internal markets (like the U.S. has) to develop competitive industries with potential for a strong position in world markets.

INSIGHTS INTO THE WORKINGS OF CONGRESS

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Dr. Andelin, Ph.D. in Low Temperature Physics, discussed the following various topics:

On the technically trained person as a member of Congress

Generally at disadvantage because concept of scientific truth is foreign to most non-scientists (Imagine getting testimony on the First Law of Thermodynamics to establish a range of expert opinions).

Advanced scientific-degree people are not easily accepted as potential congressmen and barriers exist for a working scientist or engineer to campaign effectively. Mortality rate at re-election also high.

Technically trained staff members must find ways to get technical information to Congress. Formerly rare, there are now approximately 12 Ph.D.'s on staffs, mainly as result of intern programs. (Recommend article by T. Ratchford in Physics Today for background on getting technical information to Congress.)

On the background and present state of energy legislation in Congress

A study funded by the Senate early in the term of the 92nd Congress involved 20-30 people and reported to Senator Jackson.

The Task Force on Energy report in 1972: (a) recommended action (b) accepted environmental concerns and conservation as a necessity; (c) advocated budgeting money for research and development except for oil and gas.

Concern for energy is genuine - both the Administration and Congress want energy legislation, because the people want solutions.

On the facts-of-life among Congressmen

Information to reach a congressman should be specific. It is helpful if not mandatory to have 2 page summaries aimed at the congressman's staff and then summaries of summaries not exceeding 1/2 page in length for the congressman.

Timing is essential to a congressman because he deals with specific bills at specific times. The turnover of bills is so rapid that there is a constant need for specific information which remains useful for only a few hours or days or at most, weeks.

Congressmen realize that individuals have vested interests and recognize lobbyists as such. The inability to identify an expert's vested interest often leads to discarding his information.

ENERGY OUTLOOK AT OMB

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Coal is our largest fossil fuel resource by far, and there is enough uranium to last 300 years at the present rate of consumption. With breeder reactors uranium energy supplies can be multiplied by 40. The U.S. has about 1/3 of the world's coal, and nearly 1/2 of the known uranium. We also have large deposits of oil shale.

On the subject of oil shale, Colony Development Corporation (a consortium of oil companies) is going to build an oil shale plant in Colorado. They will be able to sell oil at a profit if the price exceeds $7.00/bbl. Estimates vary from $5,000 to $10,000 per acre to revegetate and stop seepage.

Project Independence addresses the important subject of how much oil should the U.S. import. In the near future, we can probably import as much as we want unless there is another embargo but how much will it cost? What effect will imports have on this country's economy? Should we put restrictions on imports? To achieve zero imports by 1980 will require a massive expansion of the domestic coal industry. On the other hand, if we don't limit imports, by 1985 we'll probably be getting more than half our oil from abroad. The policy decision of Project Independence is to determine how much imported oil is reasonable based upon the three important factors of economics, the environment and national security.

Project Independence got off to a slow start because many felt it didn't focus on the right question. We're now putting together a range of national options with cost/benefit analyses. Some of the options are:

> Spend billions for the breeder reactor to bring it to fruition sooner.
>
> Trade; e.g., wheat for oil.
>
> Acquire a stockpile of oil.
>
> Build up excess domestic capacity. Some of this has been done already. The Elk Hills Naval Reserve in California can be brought to 100,000 bbl/day in a few days.
>
> Conservation; e.g., high prices encourage efficiency and conservation, legislate a horsepower tax and lower weights for automobiles.

The solutions to our energy problems are best posed in three time-windows: Short-term (<1983), use existing technology and nearly the same fuel mix. Mid-term (1984-2020); increase dependence on coal and uranium and press R&D on new technologies. Long-term (>50 years): Fusion, solar.

The Federal Energy Administration is in charge of Project Independence but is getting help from AEC, EPA, FPC and several other agencies. Several task forces are working on Capital, Labor, Materials, etc. The Project Independence Report is due November 1. About 300 government employees, and many industrial consultants are involved. Another policy is whether Federal Lands should be leased now for exploitation or put in public trust for future generations. This point is crucial to any decision about expanding domestic production. Peance Basin in Colorado has more oil in shale than the entire Middle East, but recovery cost will be $11.00/bbl. Note that the Defense Production Act allows the government to produce petroleum for its own needs.

The Federal Energy research and development budget for FY'75 is $1.75 billion, vs. $1.0 billion in FY'74. The division in FY'75 was 49% nuclear and 51% non-nuclear, vs. 61% nuclear and 39% non-nuclear in '74.

Nuclear fission gets $700 million, divided among LMFBR, HTGR, Fast Gas-Cooled Breeder, Molten Salt Breeder). Fusion gets $180 million; $130 for magnetic confinement and $50 million for the laser-pellet concept. Coal Research gets $600 million, which will go to study gasification, liquifaction, and land reclamation. $130 million will be for emission controls, monitoring, and effects assessment (including thermal pollution). $50 million will go for Solar Power. $45 million will go for geothermal research; $100 million for conservation (more efficient cycles, end use, storage systems, transmission and distribution, advanced automotive power systems, insulation, better control, industrial processes.) Quite a bit of study money available to universities and foundations. By way of contrast, $1.3 billion is spent for weapons development. NASA's role will by mostly supportive for ERDA; NASA has expertise in several areas. The Lewis Center is doing a study for OMB on energy conversion alternatives.

The Clinch River Breeder Reactor won't achieve good breeding ratio because of oxide fuel and a conservative lattice design. Subsequent cores will use carbide fuels. The second generation breeder will have a tighter lattice. The Clinch River plant is to the Breeder industry what Shippingport was to light water reactor industry. Less subsidies from government are expected for the 2nd generation, and the 3rd generation will probably be able to stand on its own merits and grow by itself. Sodium-cooled reactors are low pressure, which gives inherent safety advantages.

It's probably not wise to put all our eggs in the nuclear fission basket. We need to explore the potential of solar and geothermal energy. Solar energy doesn't have a feasibility problem but its harnessing is still too expensive.

ENERGY AND THE ENVIRONMENT

Earl Bailey
Associate Professor, Aerospace Engineering
University of Alabama
Tuscaloosa, Alabama

Professor Bailey emphasized the problems associated with strip mining for coal and the large scale use of nuclear energy for generating electricity. He favors a moratorium on strip mining until the environmental impacts are thoroughly understood and the undesirable aspects can be coped with. He likewise favors a moratorium on the operation of new nuclear plants until waste disposal, reactor safety and sabotage concerns are adequately studied and dealt with.

Professor Bailey emphasized that his comments were his own personal views and did not necessarily reflect the official stand of the Sierra Club. He is the National Council Representative for the Sierra Club for Alabama and Georgia. The Sierra Club does have an energy policy position and a portion of their position paper is quoted below.

"The Sierra Club believes that the long-range welfare of man and the integrity of the natural environment upon which he depends will be better served by the use of energy in a manner more consistent with the wise husbanding of the world's remaining natural resources and by the careful preservation and, if necessary, restoration of environmental quality.

"All the major sources and uses of energy must be considered simultaneously, along with their environmental consequences and their social and economic components. The Club has two main objectives:

> To promote conservation of energy resources by elimination of inefficient and unnecessary consumption of energy and thereby limit the rate of energy use to a level that produces minimal damage to the environment.
>
> To set up a system which subjects energy production and use to environmental constraints so there is no significant air or water pollution, nor loss of land. All energy facilities must conform to comprehensive regional and national land use plans.

"The Sierra Club supports the formulation and enforcement of a national energy policy that is consistent with these goals.

"Energy conservation must be made a major national goal. We must establish policies and encourage personal attitudes which promote more efficient energy use and better conservation of energy resources.

"Current and past economic policies regarding energy are a major cause of problems concerning energy supply and demand and their environmental impact. New economic policies would help promote more rational and less environmentally destructive patterns. The prices of all forms of energy should cover energy's true costs - economic, environmental, and social. When true costs are established, economics will favor energy sources which have minimum environmental impact while penalizing those with the most serious impact.

"We recommend creation of institutional structures to formulate long-range environmentally sound policy for regulating energy production, consumption, and related land use.

"The Sierra Club urges Congress to provide for the expenditure of at least $2 billion per year for a period in excess of five years for federal research and development in:

> solar, geothermal, and fusion power;
>
> efficient energy use and energy conservation;

environmental problems of hydrocarbon extraction and conversion;

stripmine reclamation;

nuclear safety and waste management;

biological and medical research in areas related to energy sources and

instrumentation for monitoring pollution.

"Nuclear power is beset with problems which are cause for great concern. The crucial problems that remain unsolved include: (a) disposal of radioactive spent fuel and wastes, (b) reactor safety, and (c) possible illegal diversion of weapons grade nuclear material. The Sierra Club opposes the licensing, construction, and operation of new nuclear fission power plants until these problems are solved.

"Because of lack of commitment to total reclamation of stripmined land by industry and government, the absence of effective federal or state land use planning, the lack of federal law and state enforcement of existing laws, and the primitive state of existing technology, the Sierra Club believes stripmining should be prohibited."

In a similar vein the Sierra Club opposes the exploitation of offshore oil and of oil shale until sufficient assurance is obtained that there will be no adverse effects on the environment.

For further information on the Sierra Club's energy position write: Sierra Club, 220 Bush Street, San Francisco, California, 94104.

PROJECT INDEPENDENCE

Gorman Smith
Deputy Assistant Administrator
Energy Resources Development
Federal Energy Administration
Washington, D. C. and

Dr. Harrison H. Schmitt
Assistant Administrator for Energy Programs
NASA Headquarters
Washington, D. C.

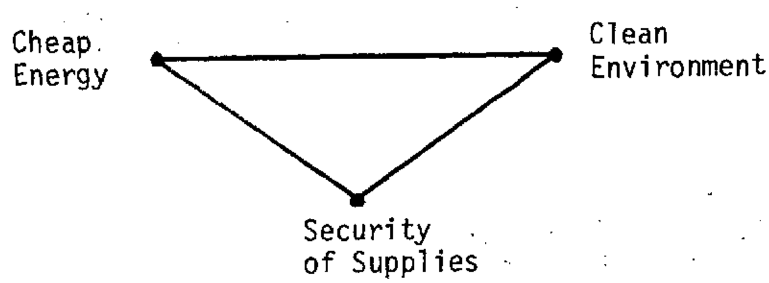
Dr. Gorman Smith saw Project Independence as similar to our study. He made the point that "Conservation must be assessed as any other resource and it has its advantages, disadvantages, and tradeoffs." One should

consider the delay of construction of power plants that leads to unemployment and lower GNP. He questioned the expression "conservation is painless." Considerable discussion ensued about different kinds of conservation, how cheap energy causes waste, why concern for the social good should cause investment in conservation technology when alternate investments return a greater dollar profit, morality, the government's role, advertisement and education. He feels that conservation will come when it is profitable for industry to conserve. He acknowledged that econometric models he had seen were inadequate to plan reduced demand and that utilities do anticipate historical growth in energy usage thus want to stimulate consumption to avoid excess generating capacity. He felt increasing costs of construction would curtail excess capacity as utilities are already canceling some planned construction. Government should stay out of the market place because whenever it gets into the market it causes undesirable disruptions.

Dr. Smith saw no way to redefine profit to include anything other than dollars. He did feel that social and environmental costs should be included in the other costs for energy but that industrial expansion should not be delayed if society is unable to determine these costs.

Westinghouse-Union Carbide has withdrawn from their projected uranium enrichment plant because utilities wouldn't sign the contracts. Financing requirements caused the contract to demand payment from the utilities even should no enriched uranium be available. Should government get into the enrichment business even more than they are at present?

Dr. Smith posed the energy dilemma in the form of a triangle.



R&D can shrink the size of the ∇ and reduce tradeoff, but the ∇ shows FEA's dilemma . . . as you move closer to one apex you move away from the other two. Questions: How do we bring in moral issues (e.g., miner safety) and reconcile these with cost? When will the Arabs lower oil prices? Where do we go from here? Dr. Smith leans toward security with low cost. The important thing lacking that Dr. Smith felt our group could do in spelling out the consequences was to pick our what we feel are the really big ones, the differences that distinguish the scenarios. Identify the differences within the group about the consequences. Ultimately, value

judgments decide the tradeoffs and direction to be taken. He said that a great national debate (the Marshall plan and Truman doctrine were cited) was necessary for a plan for the future that assumes those value judgments. Because he did not see the country ready for such a debate he thought the administration would continue to make decisions by defensive crisis management. If the problems aren't important enough they'll go away. What the political process can do is to set the rules and regulations, set standards, make them uniform, and keep them on the books for awhile. Then industry can move. Help the poor by income redistribution, not by price fixing. Considerable discussion continued about planning and the differences between energy plans, uranium history, the man on the moon, and defensive crisis management. Can the market solve the problem of true social price? Is the crisis rate too fast? Important things that need deciding via crisis management now are: (1) How independent should Project Independence be? (2) How dependent will we be on foreign uranium sources? We need come up with permits and enrichment capacity; (3) We must amend the clean air act standards or coal can not be used as an energy source.

Dr. Jack Schmitt summarized NASA's three phase scenario: (1) Phase I is the crisis phase which we are in now. It is characterized by conservation, the use of petroleum, and limited R&D. There is good reason to believe that offshore and Alaska oil fields are greater than or equal to continental fields. (2) Phase II is the transition phase characterized by much research and development. Solar energy is a big question. Some solar heating and cooling will be used but how much? There may be a transition to synthetic H_2, or CH_4. Major retooling for electric cars will take a long time. Coming on line will be regional options such as solar, geothermal and wind power. Decision on the fusion will depend on favorable R&D results. After 1985 probably no more fossil fuel power plants will be built. After 1995, no more fission power plants should be built and even including the breeder, Dr. Schmitt feels fission belongs to phase II. (3) Phase III brings on line the ultimate energy sources, which are those that are renewable. Fusion, solar, ocean thermal gradient, wind are among the renewable options and at least one or two of these sources should start contributing significantly to the energy picture by the year 2020.

ALABAMA ENERGY PICTURE

Ed Hudspeth
Chief of Energy Distribution Division
Energy Management Board
Alabama Development Office
Montgomery, Alabama

The state of Alabama has an Energy Management Board appointed by the Governor. Mr. Hudspeth covered things the board does:

Gathers relatively detailed statistics on energy production and consumption in Alabama.

Distribution Division of Board is responsible for allocation of petroleum products within context of FEA regulations. Political pressure has not been a problem.

Operation of state allocation program has been less "procedure oriented" than the Federal program.

The Energy Forecasting Conference indicates no petroleum shortage until July 1975 at the earliest, but this seems hard to accept. The FEA position is that a coal strike plus natural gas curtailment plus a hard winter would produce a crisis situation but he feels that this is unlikely, although the Alabama Board is concerned about exactly this eventuality.

Mr. Hudspeth then discussed the possibility of a superport at Mobile for oil imports by super tankers. Although his office has done several studies and has written a proposal (called the Ameraport proposal), there is no one to submit this proposal to at this time. Congress is busy with other things and has not yet passed a superport bill. The port would be 26 miles offshore so that the super tankers would be in water with a depth of 100 feet. The reason for wanting the port is the benefit to Alabama of three new refineries plus an increased tax base. The "port" would be essentially a funnel into which tankers would pump oil; during hurricanes the funnel would be empty.

One interesting effort of the Alabama Development Board is to discover by questionnaires the opinion of the people of Alabama on what should be the functional goals for education, population, energy use, and other social goals.

ENERGY CONSERVATION IN INDUSTRY

Bud R. Brown
Engineering Department
E. I. Dupont Company
Wilmington, Delaware

E. I. Dupont has been active in energy conservation since the formation of the heat, light and power group in 1903. Dupont's conservation efforts have contributed to the fact that Dupont energy use increased less than 50% in the past 10 years while Dupont (USA) production more than doubled. Sixty percent of Dupont's purchased steam is obtained as exhaust steam from electrical generating facilities. Thus waste steam is effectively used rather than being condensed and the heat discharged.

Three lucrative areas for conservation in industry are: (1) improving combustion efficiency by controlling the amounts of excess air and the final flue gas temperature; (2) reduction of losses by correcting leaks and repairing defective insulation; (3) and recovering steam condensate.

Recently Dupont changed the pressure of a proposed boiler from 400 psig to 1500 psig and by using back pressure turbines exhausting at 400 psig to drive electric generators will realize 60,000 barrel/year equivalent oil savings.

Three tools that they find virtually indispensable in an effective energy conservation program are: (1) power standards, which are used to measure the performance of a unit by taking all variables into consideration and thus alerting operators when there is potential waste or abnormal use of energy; (2) metering or instrumentation, which accurately monitors the energy use in various areas of the plant; and (3) heat or energy balances, which provide an audit of energy supplied by or to a system.

In recent studies Dupont's energy conservation consulting service has identified conservation measures that should save 14 industries the energy equivalent of 3,430,000 barrels of oil in one year. Their experience indicates that a significant energy conservation effort at an industrial plant will, on the average, result in about a 7% to 15% reduction in the plant's total energy use. If all industry had made this effort in 1970, and an average of 10% had been saved, about 1 1/2 million barrels of oil per day would have been saved.

There is a shortage of people with energy conservation skills. Dupont has to train their own.

APPENDIX G. UNITS AND CONVERSION FACTORS

ENERGY UNITS

In spite of attempts to institute a universal set of physical units, there are units of measure that are peculiar to various segments of industry. Thus, in order to compile data for all of industry, unit equivalences must be known.

The British Thermal Unit (BTU) is the basic unit of energy in many measurements. The quad is one quadrillion or 10^{15} BTU. The quad should not be confused with the Q which has been used in the past and was defined as 10^{18} BTU.

The barrel, used as an energy unit, refers to the standard barrel (42 gallons) of crude oil and is defined as having an energy content of 5,800,000 BTU. Thus, the energy content of any fuel can be expressed in barrels of crude oil equivalent (BCOE). For instance, heavy distillate has a higher energy content than crude oil (6,960,000 BTU/bbl.) so that its energy rating is 1.2 BCOE/bbl. The equivalent energy value of crude oil plus natural gas liquids, NGL (5.5×10^6 BTU/bbl.) is .95 BCOE/bbl. This combination is peculiar to oil and gas production statistics.

PLANT RATINGS

The ratings of some facilities may seem incongruous as a result of the definition of the barrel as an energy unit. Thus, a hydroelectric power station may be rated in barrels, but the rating refers to the amount of fossil fuel energy that would be needed for a steam power plant to produce the same electrical output.

Further, care must be exercised when power plant capacities are considered. In some instances, a plant's rating is based on the gross value of fuel energy consumed by the plant when it is operating at its rated output. On the other hand, the rated output is frequently used to describe plant capacity. For example, a nuclear power plant having a rated electrical output of 1.0 GW could be receiving 3.0 GW thermal energy from the fuel in its reactor. When using published plant data, one must ascertain which parameter is being used.

To further complicate the picture, it must be realized that virtually no power plant can be operated continuously, year after year, with no down time. For this reason, a power plant's long term contribution to a power system is less than its full load rating. A plant factor is established depending on the operating experience in a system. As an example, a nuclear power plant must be shut down periodically for refueling. This, coupled with equipment malfunctions, necessitates significant down time. Presently, the nuclear power generation industry is striving to bring the plant factor up to 80 percent.

NUCLEAR FUELS

There is some confusion in the energy values assigned to nuclear fuels. Much depends on the assumptions made. A "burner" type nuclear reactor (as opposed to a "breeder" reactor) with a capability of converting 1.0 percent of the uranium fuel to energy will produce about 10^{10} BTU per ton of ore containing 1.5 percent uranium.

Pure yellowcake, containing 100 percent U_3O_8, fueling the above reactor will produce about 6×10^{11} BTU per ton.

Uranium dioxide, UO_2, enriched so that it contains 3.0 percent of U-235, will provide 2.5×10^{12} BTU/ton of U_3O_8.

ENERGY EQUIVALENTS

1 barrel (42 gallons) of crude oil = 5.8×10^6 BTU
1 barrel of crude oil + NGL = 5.5×10^6 BTU
1 cubic feet of natural gas = 1035 BTU

1 BTU = 1055 joules
1 Kilowatt = 10^3 watts electrical
1 Megawatt = 10^6 watts electrical
1 Gigawatt = 10^9 watts electrical
1 Kilowatt hour = 3412 BTU
1 Quad = 10^{15} BTU
1 Quad = 1.724×10^8 barrels
1 Quad = 40×10^6 short tons of coal
1 Quad = 9.662×10^{11} ft.^{3} of natural gas
1 Quad = 70×10^6 short tons of lignite

APPENDIX H. STUDY ORGANIZATION

The Summer Faculty Systems Engineering Design Program is jointly sponsored by the National Aeronautics and Space Administration and the American Society for Engineering Education. The eighteen participants are teachers in fields in science and engineering. Three of the group have backgrounds in economics, environmental science and political science. The administrative staff was composed of staff members from Auburn University the University of Alabama, and the Marshall Space Flight Center.

The purpose of the program was to apply the principles of system design to the nation's energy problem. Chapter 2 describes the systems design method.

A vital feature of the systems design program is the interaction among the participants. Meetings of large and small groups occurred on a daily basis. In this fashion, personal points of view and biases were exposed to group criticism and comment. A fundamental concern was that the objectivity of the study be maintained. Project and task group leadership positions were rotated to provide leadership experience for as many of the participants as possible.

The eleven-week program was divided into three equal interim periods. The first two periods were devoted largely to definition of an objective and attendant requirements and to the study of alternatives. Data gathering was very broad based. Speakers from government, industrial, and other sectors presented talks on the current state of energy resources, production and utilization. Key individuals all over the U. S. were contacted by telephone, letter and, in some instances, by personal visits. The extensive resources of the Redstone Scientific Information Center Library, as well as current periodicals and professional journals, were diligently searched. The speakers summaries are in Appendix F.

In order to facilitate the collection and analysis of data, four task groups were formed (see Figure H-1). The energy source group placed the major emphasis of their study on coal, natural gas, petroleum and uranium. The generation and conversion group considered fossil fuel electric power plants, nuclear power plants, solar thermal power plants, solar heating and cooling of buildings, and synthetic fuels. Railroads, oil and gas pipelines, ships, electric power lines and coal-slurry pipelines were studied by the task group on distribution. The utilization group covered residential and commercial usage, industrial usage and transportation. It should be noted that initially the coverage of each group was much broader, but when the technical, economic and political aspects were

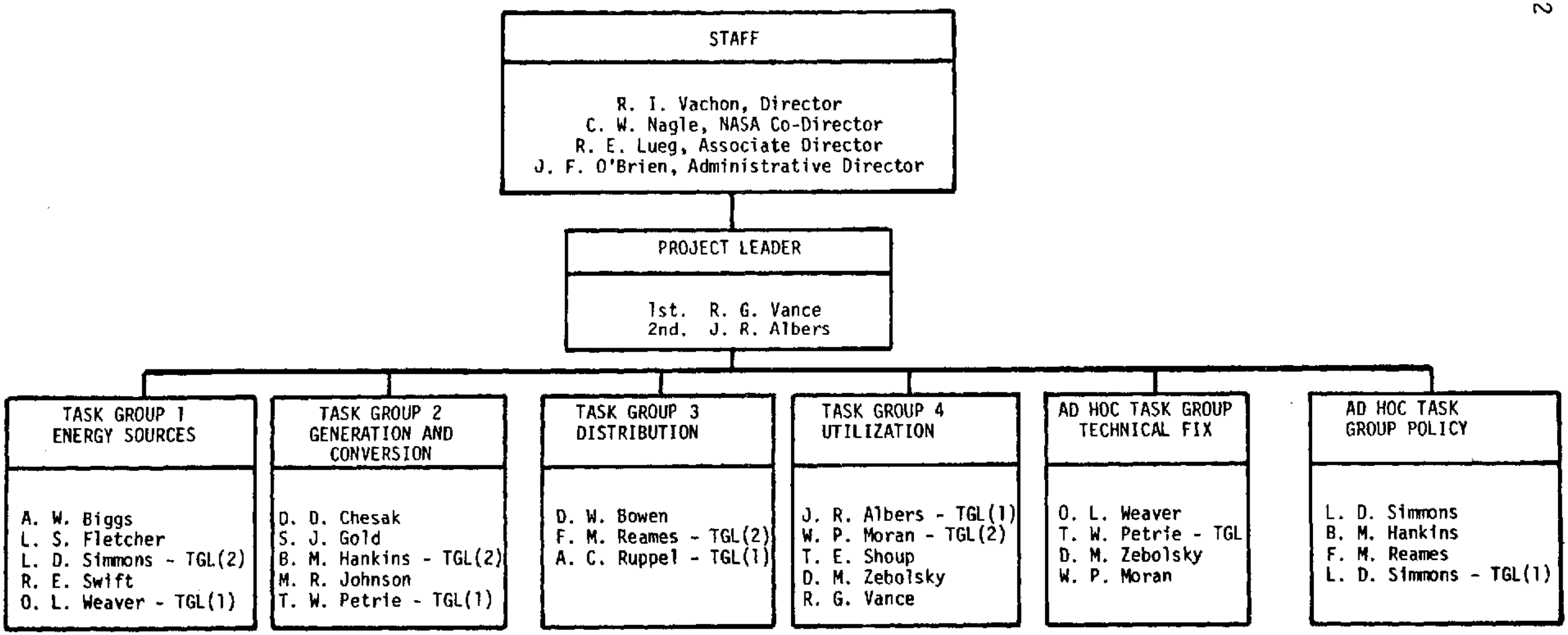
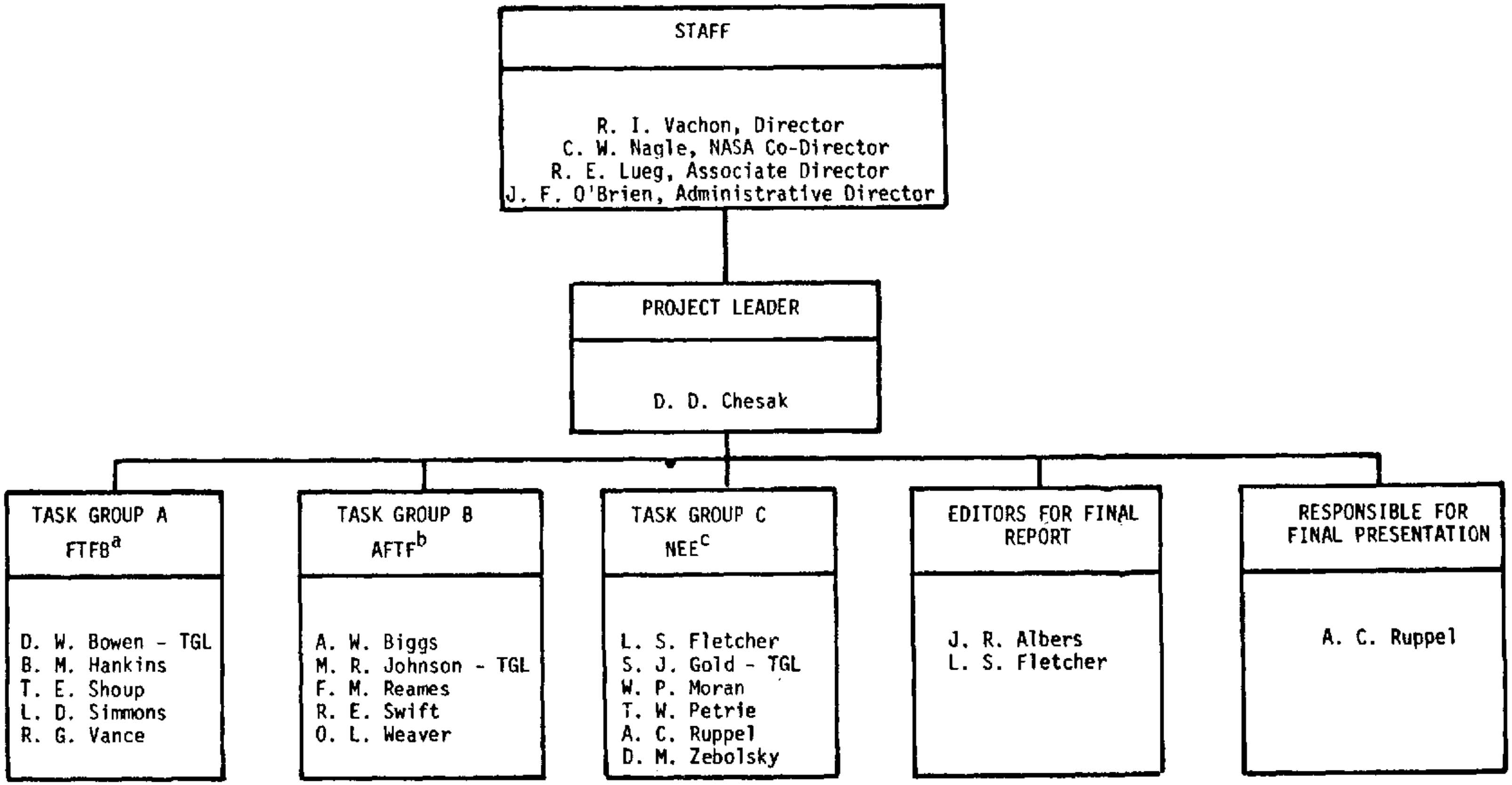


FIGURE H-1 ORGANIZATIONAL CHART - FIRST AND SECOND INTERIM PERIODS

considered, a large number of categories were foreseen to have very little influence on the nation's energy situation in the next few decades and were not retained for further study.

As the study evolved, it became evident that in-depth studies of some of the proposed national energy scenarios would be useful. Of the many proposals advanced by various agencies, two were selected: the Nuclear Electric Energy Economy and the Ford Foundation Technical Fix. In addition, a third scenario, a modification of the Ford Technical Fix, was formulated by the group. The task groups compiled data on the major elements needed to bring about the projected growth in the energy industry. Statistics on men, materials and capital requirements were considered for each scenario. These elements were then summed for each of the three cases.

Because three scenarios were selected for consideration and because expertise from each general area was needed, i.e., sources, conversion and generation, distribution and utilization, three task groups were formed for the third interim period (see Figure H-2). These new task groups then assessed the impacts that the implementation of each of the scenarios would have on the social, environmental, economic and political sectors of the nation.



[a]Ford Technical Fix, Base Case
[b]Alternate to Ford Technical Fix
[c]Nuclear Electric Economy

FIGURE H-2 ORGANIZATIONAL CHART - THIRD INTERIM PERIOD

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1971	STARSITE - Search to Assess Resources, Social, Institutional, Technical, and Environmental
1972	ERISTAR - Earth Resources Information Storage, Transformation, Analysis, and Retrieval
1973	TERRASTAR - TERRestrial Application of Solar Technology And Research